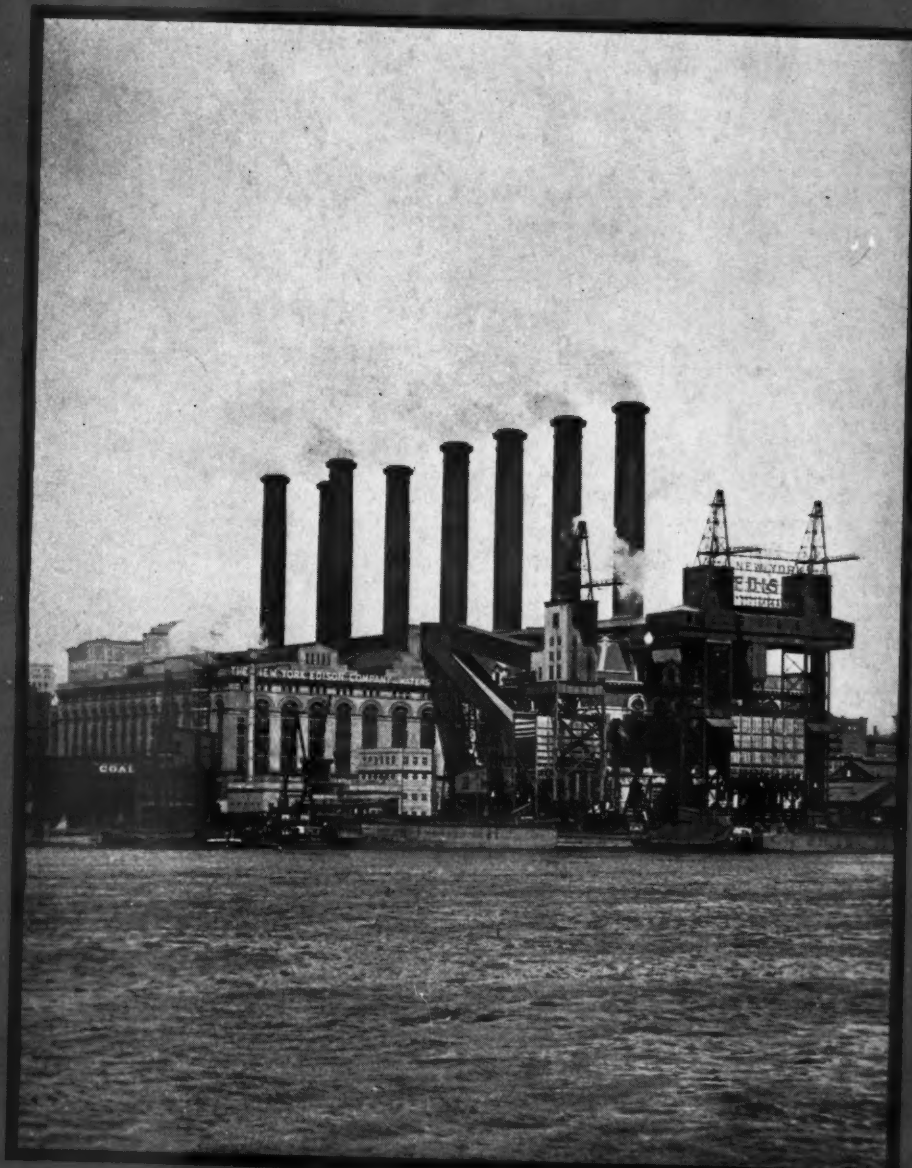
COMBUSTION

Vol. 4, No. 11 MAY, 1933 25c a copy



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DRAFT MEASUREMENT

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DROUGHTS AND THEIR INFLUENCE ON THE QUALITY OF WATER FOR INDUSTRIAL USES

COMBUSTION

VOLUME FOUR • NUMBER ELEVEN

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DEPARTMENTS

H. STUART ACHESON, *General Representative* | CHARLES McDONOUGH, *Editor* | F. H. ROSENCRANTS, *Associate Editor*

COMBUSTION is published monthly by In-Ce-Co Publishing Corporation, a subsidiary of International Combustion Engineering Corporation, 200 Madison Avenue, New York. London office, Aldwych House, Aldwych, W.C.2. Joseph V. Santry, President; George H. Hansel, Secretary; W. I. Branigan, Treasurer.

SUBSCRIPTIONS, including postage, United States, $2.00, Great Britain, $2.50 a Year. Canada $3.00 (includes Canadian tax). Other countries, $3.00. Single copies: 25 cents.

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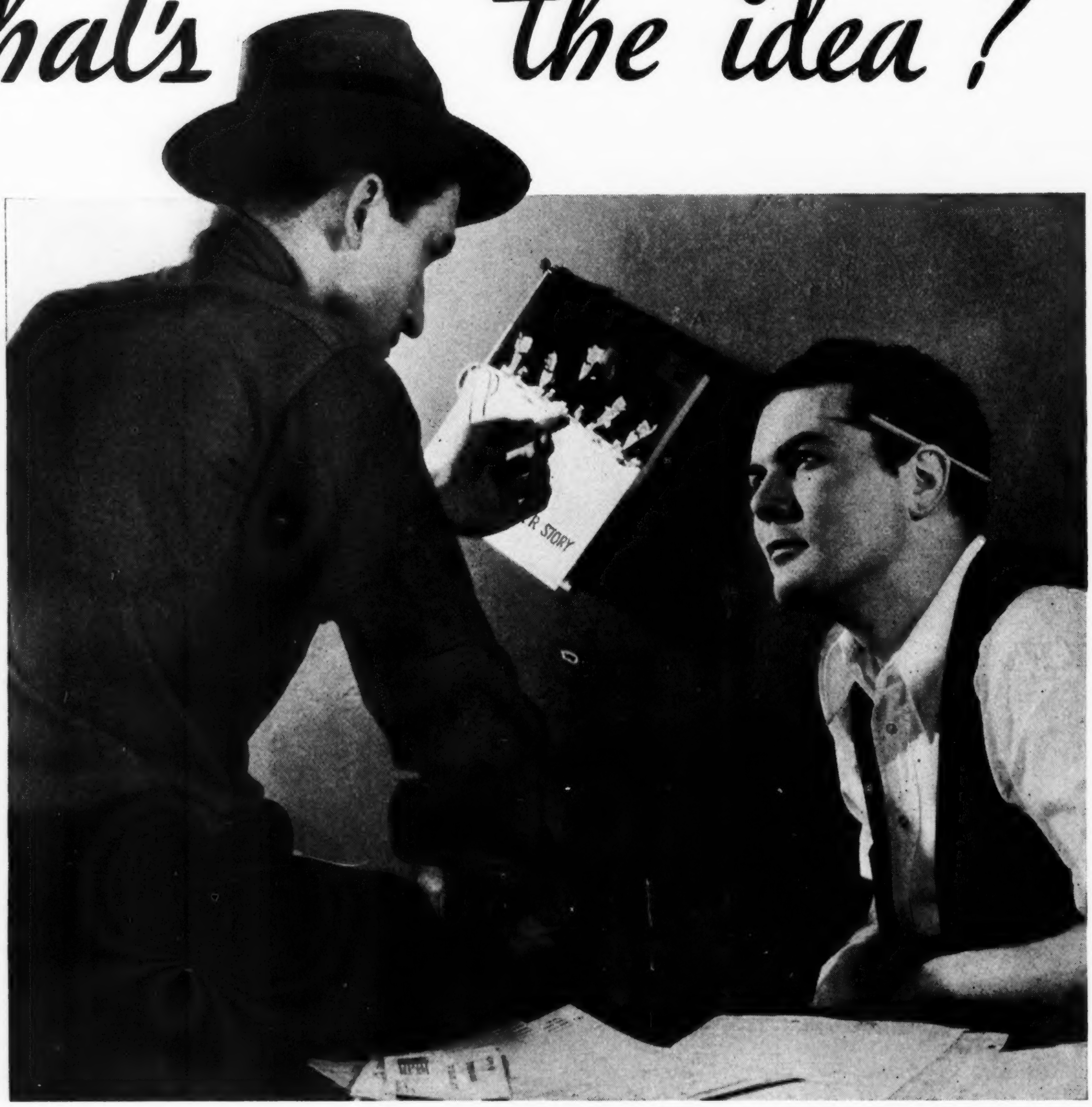

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Commentary by Joseph H. Keenan

The International Temperature Scale

It was a robber's daughter, and her name was Alice Brown,
Her father was the terror of a small Italian town;
Her mother was a foolish, weak, but amiable old thing;
But it isn't of her parents that I'm going for to sing.

Bab.

I have discussed the two kinds of Kelvin Scale thermometers, but in one sense their offspring, the platinum resistance thermometer, is more important than either of them. The utility and significance of the thermodynamic scale have been recognized ever since Lord Kelvin proposed it, but the formidable problems of gas thermometry still make it impracticable as a standard of temperature. In the interest of uniformity Professor Callendar urged the world to abandon for a while the scattered and discordant attempts to express temperatures in terms of the Kelvin Scale and to adopt a temperature scale defined in terms of the electrical resistance of platinum. Today, within the range of steam temperatures used in power plants, the platinum resistance thermometer is the formally adopted international standard of thermometry. All measuring instruments are calibrated against it and all precise experimental work is reported in terms of the International Temperature Scale which it defines.

The platinum resistance scale makes pretense to no greater virtue than its approximation to the Kelvin Scale. It has the same interval of 100 degrees between the freezing and boiling points of water and its value at the sulphur boiling point (444.60 degrees) was fixed in accordance with the best measurements of that point on the Kelvin Scale. In between the relationship between resistance and temperature is expressed by a quadratic equation because that type of equation appeared to be the simplest and best representation of the more reliable Kelvin Scale measurements.

The founders of the International Scale included in its definition the statement, "the Thermodynamic Centigrade Scale . . . is recognized as the fundamental scale to which all temperature measurements should ultimately be referable." In this somewhat regretful spirit they set up the international standard. It is admittedly an expedient to avoid confusion until our experience with the thermodynamic standard is more complete.

Nevertheless we have had great confidence in the coincidence of the International Scale with the Kelvin Scale. We derive thermodynamic relationships which are true only for the Kelvin Scale and apply them to experimental data based on the international standard. Perhaps the most common example is the Clapeyron relation. From Carnot's principle and the definition of the Kelvin Scale we find that the work done by any Carnot cycle between temperatures T and T-dT is the heat added from the heat source multiplied by the efficiency, dT/T. If the heat added is just enough to evaporate completely a certain amount of saturated liquid then it is equal to the latent heat of the vapor produced. But the work done by the engine using this much vapor can also be calculated from the p, v diagram or indicator card by multiplying the change in volume during vaporization by the pressure drop corresponding to dT. Equating these two expressions for the work of the cycle we get

$$L\ dT/T = (v_g - v_f)\ dp$$

or

$$L = T\ (v_g - v_f)\ dp/dT.$$

From this we can calculate the latent heat if we know the specific volumes of vapor and liquid and enough of the pressure-temperature relation along the saturation line to determine the pressure-temperature slope. This page from the liturgy of thermodynamics has forever wedded latent heat with specific volume.

We have a nice example of the workings of the Clapeyron relation within the American steam research program. At the Bureau of Standards, Osborne has measured latent heats, while at M. I. T., Keyes has measured specific volumes of liquid and vapor. The disagreement is small, but it sometimes exceeds the probable error in either measurement.

It is time, now, to recall that the Clapeyron equation is valid only when experimental values are expressed in terms of the Kelvin Scale of temperature, an impossible requirement in the present state of thermometry. So it is well to investigate the probable differences between the International Scale and the Kelvin Scale. We find at 400 cent. a difference of almost one degree between the best available Kelvin Scale thermometry and the International Scale, while the precision attained in steam research, using of course the International Scale, is about 1/100 of one degree. The precision in our present experimental knowledge of latent heats and vapor volumes is something like 1/20 of one per cent, but the Clapeyron derivative, dp/dT, in terms of the Kelvin Scale has uncertainties greater than ½ of one per cent at the higher pressures. The discrepancies between volume measurements and latent heat measurements are well within this uncertainty and they will doubtless be reduced as our knowledge of the Kelvin Scale improves.

Long before experiment had progressed to the point where the difficulty was apparent, Dr. Keyes was warning us of it. More than that, he and his colleagues embarked on an experimental comparison of the Kelvin and International Scales with their usual thoroughness and skill. As a result of their work and of other investigations inspired by it, we can look forward to a day not too remote when the Kelvin thermometer will be the practical standard of temperature and the present International Scale will exist only in the history of science.

Joseph H. Keenan
Stevens Institute of Technology

EDITORIAL

Reputation

WE were discussing an arrangement for pulverized fuel firing with an engineer employed by a pulverized fuel equipment manufacturer. He was criticizing it as having no advantages other than low first cost, when we interrupted to say, "Well, that may all be true, but the fact remains that a number of such installations have been made and presumably they are reasonably successful; otherwise, the practice would not continue."

"Oh, yes," he said, "they'll work after a fashion, but they will be neither efficient nor satisfactory. I saw such an installation recently. My company had lost the job because a competitor, a company with relatively little standing or engineering background, had been able to quote a lower price due primarily to the use of this arrangement. The job was working but the results expected were not being obtained and conditions were developing which would subsequently mean excessive outage."

Again we interrupted, "But won't the seller of the equipment have to 'make good' and therefore be the loser in the end?"

"No," he said, "guarantees don't cover everything and where they are explicit on important aspects of performance, tests can be run which apparently meet them. The customer will have to live with the job for a while before he realizes the extent of his mistake. There are always two sides to an argument and he'll find that his complaints don't get him very far. The equipment seller may lose his reputation in that plant but that doesn't mean much to him. There are lots of others and before his troubles catch up with him he will have obtained a number of jobs by underbidding companies whose reputations mean too much to them to permit departures from good engineering and proper construction. I don't mean to imply that my company never makes mistakes but when we do we stick with the job until it is operating satisfactorily, and that costs money. Consequently we can't afford to take chances on constructions which do not meet our engineering standards. Of course, in these days, when first cost is often being given more consideration than those factors which assure year-in and year-out operating economy and reliability, the maintenance of such standards results in our losing jobs to cheap competition but when wiser buying returns, as it is certain to, we will still have our reputation."

This fragment of a conversation is not related here as an exact report. It is, however, the substance of what was said and it truly reflects a state of affairs which has been very discouraging to companies that have attached major importance to the maintenance of standards which assure to the buyer the results he really wants and expects. Unfortunately most buyers are not technically competent to determine the relative performance values of different manufacturers' equipment. Consequently they must rely largely on the integrity and experience of those competing for their business.

This is particularly with respect to the principal items of boiler plant equipment. Failure to select the most suitable type of firing equipment, boilers, etc., and to assure proper design, manufacture and installation will quickly result in losses greatly exceeding any saving obtained by buying on a price basis only; and these losses will continue throughout the lifetime of the equipment. Under such circumstances the equipment manufacturer's reputation, which is the product of his integrity, ability and experience, is obviously a factor of first importance to the buyer. To disregard it in order to take advantage of a low price is foolhardy.

Combustion Rates

A READER writing the author of the article "The Selection of Stokers" (April issue) said: "Your article merits a medal for frankness in stating facts. I don't suppose the 50-70 lb. combustion rate fanatics will heed it much, but I hope the saner business men will." His letter concluded with this sentence, "Here's hoping that business picks up so that the man who buys may apply the *sound engineering* of your article and avoid hysterical expectancies."

The author of the article referred to criticized extremely high combustion rates not so much because of the difficulties of obtaining them as because of the operating evils which attend them. They are attempted and sometimes guaranteed principally because of the buyer's desire to get boiler ratings which will make it unnecessary for him to buy an additional unit or larger stokers. Combustion rates of the order mentioned above have been obtained in a few cases under exceptionally favorable circumstances, but in the present development of the art, they are not practical. Generally speaking, they mean greatly reduced efficiency, excessive carbon loss, clinker troubles, high maintenance cost and decreased availability. Occasionally there may be situations where the economics involved will justify these losses and difficulties but such cases are rare.

There is always a tendency to over-rate and overtax equipment which is inherently flexible in its capacity. This tendency becomes more pronounced in hard times when keen price competition often leads to extravagant performance promises. *Sound engineering* is the means of keeping this tendency under control. While such engineering is essentially progressive and should persistently seek higher performance levels, it must also be practical and must, therefore, take cognizance of economic limitations. In the case of equipment having a flexible rate of output, sound engineering will be exercised when a proper balance between capacity, efficiency and economy are achieved. The rating of stokers on this basis will assure the most satisfactory as well as the most economic performance.

Draft Measurement*

By WM. L. DE BAUFRE

Chairman, Department of Applied Mechanics,
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Accurate draft measurement has become increasingly important with the development of large modern boiler units. The author presents a thorough and fundamental discussion of the factors affecting the accuracy of draft measurements and the corrections which must be made in interpreting such measurements. A subsequent article will be devoted to the frictional resistances encountered by air and the products of combustion in flowing through furnace and boiler settings.

IN order to burn fuel in the furnace of a steam boiler or other heat absorbing device, it is necessary to supply atmospheric air for combustion and to withdraw the gaseous products of combustion. The rapidity of flow of atmospheric air and of products of combustion through a furnace and boiler setting is sometimes referred to as the draft. The meaning of the word draft should be limited, however, to the pressure difference associated with the flow rather than to indicate the rate of flow.

Draft is usually measured by means of a U-tube containing water or a light oil. When one end of the U-tube is open to the atmosphere and the other end is connected by a pipe to a point in a furnace or boiler setting, the difference between the heights of the water or oil in the two legs of the U-tube is the draft at that point in the furnace or boiler. If both ends of the U-tube are connected to different points in the setting, the differential reading is the difference in the drafts at those two points.

The measurement of draft thus appears to be a very simple matter. And so it is for small furnaces and boilers, particularly where great accuracy is not required due to a chimney furnishing more than ample draft to produce the required flow of air and products of combustion through the furnace and boiler setting. In large modern furnace and boiler installations, however, where accurate calculations must be made for selecting the forced and induced draft fans, it has sometimes been found that the draft so measured does not check with the pressure difference calculated as necessary for the flow of air and products of combustion through the furnace and between the boiler tubes. There are several possible explanations for such discrepancies.

These explanations will be brought out in discussing the various factors upon which the accuracy of draft measurement depends, including density of liquid used in the draft gage and variation with temperature, variation of gravity over the earth's surface, surface tension of the liquid used, density of air column in the connecting pipes, leakage in connecting pipes, shape and size of opening in setting, velocity head, measurements in tube banks, and stack effect. The velocity head and stack effect do not affect the accuracy of draft measurements, but their values must be utilized to calculate the frictional resistance to fluid flow between two points in a setting when the draft at each point is known.

Of course the draft gage itself may have defects which introduce large errors in its indication, but the calibration of draft gages will not be discussed. It will be assumed that the draft gage has straight tubes of uniform bore, has accurate scales and is otherwise mechanically perfect; also, that the gage is mounted in a truly vertical position or at the proper angle if of the inclined type.

Density of Liquid in Draft Gage and Variation With Temperature

Measurements of draft are usually expressed in inches of water; but as the density of water varies with its temperature, a given height of water column in a draft gage does not always measure the same pressure difference. The density of pure water from 32 to 140 fahr. is given in Table 1 in pounds per cubic inch. This unit of density has been chosen because the tabulated values then represent the pressure in pounds per square inch corresponding to one inch of water column at each temperature. The densities of pure water in Table 1 were obtained from Volume III of the International Critical Tables. In these tables, however, the density is given in grams per milliliter. To convert to pounds per cubic inch, the conversion factor is $2.204622/(0.3937^3 \times 1000.027) = 0.0361265$, where 2.204622 lb. are equivalent to one kilogram, 0.3937 inch is equivalent to one centimeter, and 1000.027 cu. cm. is the volume of one liter, which is defined as the volume of 1000 grams of pure water at its maximum density.

The standard density of water for pressure measurements has sometimes been taken as the maximum density of pure water, which occurs at about 39 fahr. (4 cent.). This selection was undoubtedly due to the attempt to define unit mass in the metric system as that of one cubic centimeter of pure water at its temperature of maximum density, so that in the metric system the density of pure water is practically unity at 4 cent. It is preferable, however, to take the standard density for pressure measurements nearer to room temperature.

Probably 60 fahr. (about 15 cent.) is preferable to any other temperature due to the fact that gas densities and petroleum densities are standard at that temperature. The density of pure water at each temperature in Table 1 has therefore been divided by the density at 60 fahr. in order to get a factor by which water column readings at any temperature may be multiplied to obtain the corresponding height at 60 fahr. An inspection of these factors will indicate whether such a correction is necessary to obtain the accuracy desired in any particular case.

While draft measurements are usually expressed in inches of water, a light petroleum oil is commonly employed in draft gages. Density determinations upon an oil from a well known make of draft gage gave a density variation with temperature corresponding fairly closely with the ratios for 38-degree A.P.I. petroleum oil in Table 2 of the National Standard Petroleum Oil Tables, Circular No. 154 of the U. S. Bureau of Standards. The ratios in Table 1 for a typical draft gage oil were therefore taken from Table 2 in this Circular to correspond to 38-degree A.P.I. oil. If a draft gage oil should have another density at 60 fahr., the corresponding ratios can be obtained from the same table which covers a wide range in densities. If a draft gage reading at any temperature is multiplied by the proper ratio from Table 1 or from this Circular, the corresponding reading is obtained at the standard temperature of 60 fahr.

TABLE I—DENSITY OF WATER, DRAFT GAGE OIL AND MERCURY

	Water		Typical draft gage oil		Mercury	
Temp., fahr.	Density, lb. per cu. in.	Ratio to water at 60 fahr.	Density, lb. per cu. in.	Ratio to oil at 60 fahr.	Density, lb. per cu. in.	Ratio to mercury at 32 fahr.
0	......	.....	0.03097	1.0278	0.49275	1.0032
5	......	.....	0.03090	1.0255	0.49250	1.0027
10	......	.....	0.03083	1.0232	0.49225	1.0022
15	......	.....	0.03076	1.0209	0.49200	1.0017
20	......	.....	0.03069	1.0185	0.49175	1.0012
25	......	.....	0.03062	1.0162	0.49150	1.0007
30	......	.....	0.03055	1.0139	0.49126	1.0002
32	0.03612	1.0008	0.03052	1.0130	0.49116	1.0000
35	0.03613	1.0009	0.03048	1.0116	0.49101	0.9997
40	0.03613	1.0009	0.03041	1.0093	0.49076	0.9992
45	0.03612	1.0009	0.03034	1.0069	0.49051	0.9987
50	0.03612	1.0007	0.03027	1.0046	0.49027	0.9982
55	0.03611	1.0004	0.03020	1.0023	0.49002	0.9977
60	0.03609	1.0000	0.03013	1.0000	0.48978	0.9972
65	0.03607	0.9995	0.03006	0.9977	0.48952	0.9967
70	0.03605	0.9989	0.02999	0.9954	0.48928	0.9962
75	0.03603	0.9983	0.02992	0.9931	0.48903	0.9957
80	0.03601	0.9976	0.02985	0.9908	0.48878	0.9952
85	0.03598	0.9968	0.02978	0.9884	0.48854	0.9947
90	0.03595	0.9959	0.02971	0.9861	0.48829	0.9942
95	0.03591	0.9950	0.02964	0.9838	0.48805	0.9937
100	0.03588	0.9940	0.02957	0.9815	0.48780	0.9932
105	0.03584	0.9930	0.02950	0.9792	0.48756	0.9927
110	0.03580	0.9919	0.02943	0.9769	0.48731	0.9922
115	0.03576	0.9907	0.02936	0.9746	0.48707	0.9917
120	0.03571	0.9895	0.02930	0.9723	0.48682	0.9912
125	0.03567	0.9883	0.02923	0.9700	0.48658	0.9907
130	0.03562	0.9869	0.02916	0.9677	0.48633	0.9902
135	0.03557	0.9856	0.02909	0.9654	0.48609	0.9897
140	0.03552	0.9842	0.02902	0.9631	0.48584	0.9892

The density in pounds per cubic inch of a typical draft gage oil at 60 fahr. was obtained by multiplying the density of pure water at 60 fahr., namely, 0.036092 lb. per cu. in., by 0.8348, the specific gravity of 38-degree A.P.I. oil as given in the above mentioned Circular. The oil density at 60 fahr. was then multiplied by the tabulated ratio at each temperature to get the corresponding oil density at that temperature. It should be noted that these oil densities do not apply directly to readings of draft gages using oil unless the scales are graduated in standard inches. Usually, the graduations are such as to indicate the pressure difference in inches of water instead of inches of oil. The proper ratios, however, are directly applicable in the latter case to reduce the readings to the standard temperature of 60 fahr.

The density of mercury from 32 to 140 fahr. is included in Table 1 because mercury is also employed for differential pressure measurements. It is internationally customary to reduce mercury column readings to the standard mercury density of 13.5951 grams per cubic centimeter at the temperature of melting ice. Using the conversion factor $2.204622/(0.3937^3 \times 1000) = 0.0361275$, the corresponding standard mercury density in English units is 0.491157 lb. per cu. in. at 32 fahr. The ratios for mercury in Table 1 were obtained by means of the following relation derived from the coefficients of cubical expansion of mercury given in the Smithsonian Physical Tables:

$$v_t = v_{32}\ [1 + 0.00010101\ (t - 32) + 0.0000000024\ (t - 32)^2]$$

where v_t is the volume at any temperature t of a mass of mercury having the volume v_{32} at 32 fahr. The density of mercury at temperature t was obtained by multiplying the standard density at 32 fahr. by the ratio v_{32}/v_t.

When the temperature of a draft gage or similar instrument varies, the scale changes in length as well as the liquid in density. The linear expansion or contraction of the scale reduces the temperature error due to change in density of the liquid. But as the coefficient of linear expansion of a brass scale is only 0.0000102 per deg. fahr., this reduction is less than one-tenth of the temperature error with mercury, which in general expands or contracts less than water or oil with change in temperature. The linear expansion of the scale may therefore be neglected except in very accurate measurements. Convenient tables are found in the Smithsonian Meteorological Tables for correcting mercury barometer readings to the standard mercury density at 32 fahr., the corrections including the effects of changes of both mercury density and scale length with temperature.

The scales on draft gages are usually adjustable in order to set the liquid level to read zero on the scale for zero pressure. The draft is then determined by the liquid level reading on the scale at any instant. If the temperature of the gage changes, an error is then introduced into the reading by reason of the relative expansion of the liquid and the glass parts of the gage holding the liquid. As this error is the same at all readings of the gage, it may be eliminated by resetting the scale for the zero reading. It is desirable to check the zero reading of draft gages occasionally, particularly during a test of a furnace or boiler, in order to eliminate this particular temperature error, which is in addition to the temperature error previously described. This particular temperature error does not occur when the draft is measured by the difference in levels in the two legs of a U-tube rather than by the liquid movement in one leg from the zero reading.

Variation of Gravity

Another error for which a correction is necessary only in case of extreme accuracy, is that due to varia-

tion in the force of gravity over the earth's surface. By international agreement, standard gravity corresponds to an acceleration of 980.665 cm. per sec. per sec. of a body falling in a vacuum. Where the force of gravity is different from the standard value, a greater or less height of liquid column is required to balance a given pressure difference than at the location of standard gravity, which occurs approximately at 45 degrees latitude and sea level. The gravity correction is

$$\Delta h = \frac{g_o - g}{g_o} h$$

where g_o = 980.665 cm. per sec. per sec. or 32.1740 ft. per sec. per sec., standard acceleration of gravity.
g = local acceleration of gravity in same units, and
h = measured height of liquid column.

At the equator and sea level, g = 32.089 ft. per sec. per sec., or 0.99737 times the standard acceleration of gravity. At the poles and sea level, g = 32.259 ft, per sec. per sec., or 1.00265 times the standard acceleration of gravity. For each 1000 ft. above sea level, g is reduced approximately 0.0031 ft. per sec. per sec., or about 0.0001 times the standard acceleration of gravity. These values show that corrections for variation in gravity are rarely if ever necessary in draft measurements.

Surface Tension of Liquid

If a simple U-tube having bores of equal diameter in the two legs is used for draft measurement, the tendency for the water or oil to be elevated in one leg by reason of surface tension of the liquid is balanced by an equal tendency in the other leg. Often, however, one leg consists of a tube of small bore while the other leg is a reservoir of comparatively large diameter. In the reservoir, the surface tension effect is nearly zero. In the small bore tube, however, the surface tension may produce an appreciable elevation of the liquid as indicated by the data in Table 2. The approximate ele-

TABLE II—APPROXIMATE ELEVATION OF WATER AND DRAFT GAGE OIL AND DEPRESSION OF MERCURY DUE TO SURFACE TENSION

Bore, inch	Factor	Elevation of water, inch	Elevation of oil, inch	Depression of mercury, inch
0.1	0.60	0.276	0.120	0.138
0.2	0.40	0.092	0.040	0.046
0.3	0.30	0.046	0.020	0.023
0.4	0.20	0.023	0.010	0.012
0.5	0.13	0.012	0.005	0.006
0.6	0.08	0.006	0.003	0.003
0.75	0.05	0.003	0.001	0.002

vations of water and draft gage oil and the depressions of mercury in Table 2 were calculated by means of the factors in the second column and a theoretical formula for surface tension.

This theoretical formula is

$$h = \frac{4\lambda}{\rho g d}$$

where λ = surface tension of liquid in dynes per cm.,
ρ = density of liquid in gm. per cc.,
g = 980.665 cm. per sec. per sec.,
d = bore of tube in cm. and
h = elevation or depression of liquid in cm.

For water, λ = 72.75 dynes per cm. at 20 cent. according to the International Critical Tables. Substituting this value and reducing to inches, we have for water:

Theoretical elevation (inch) = 0.046/Bore (inch).

For 38-degree A.P.I. petroleum oil, λ = about 26 dynes per cm. from a curve for variation with density in the International Critical Tables. Hence, for a typical draft gage oil,

Theoretical elevation (inch) = 0.020/Bore (inch).

For mercury in contact with atmospheric air, λ = 491.2 dynes per cm. at 17.5 to 19.5 cent. (Physikalisch-Chemische Tabellen). Therefore, for mercury,

Theoretical depression (inch) = 0.023/Bore (inch).

Mercury is depressed because it does not wet glass as is the case with water and oil which are elevated by surface tension.

The factors in Table 2 were obtained by comparing the actual depressions for mercury given in Volume III of Glazebrook's Dictionary of Applied Physics with the values calculated by the above formula for mercury. The same factors were used for water and oil although it is probable that the theoretical elevations of water and oil are not reduced as much as these factors for mercury would indicate. Instead of using the elevations given in Table 2 to correct draft gage readings, a zero pressure reading should be taken to determine the correction in any particular case. This is possible because the surface tension error is the same at all readings if the tubes are of uniform bore.

Due to surface tension, the liquid level within a tube is not horizontal but is rounded, and this rounded surface is known as the meniscus. The correction for surface tension is expressed more nearly accurately in terms of the height of the meniscus and the bore of the tube than in terms of the latter alone, as in Table 2. See tables in Glazebrook's Dictionary of Physics and in Mark's Handbook for Mechanical Engineers.

When a pressure is measured by getting the difference between the readings of the liquid levels in the two legs of a differential gage and then applying corrections for the surface tension effects in the two legs, the readings should be taken at the bottom of the meniscus for water and for oil and at the top of the meniscus for mercury. When the pressure is obtained by subtracting the zero reading in either leg from the pressure reading in the same leg, both readings may be taken at any point in the meniscus provided the same point is taken for each reading. This method of using a differential gage eliminates the error due to surface tension because it is the same in amount at both the zero and the pressure readings.

Air Columns in Connecting Pipes

Questions sometimes arise as to whether draft gages should all be mounted on the same level or should each be placed at the level of the point in the setting to which the gage is connected. Neither requirement is necessary, as will be shown in discussing the effects of air columns in the connecting pipes between a draft gage and the setting.

The ideas involved may be brought out by first considering the effects of water columns in the connecting pipes of a mercury differential gage used to measure the pressure drop between two points in a steam pipe.

Thus, in Fig. 1, let p_1 and p_2 be the gage pressures at the two points in a steam pipe and let b inches of mercury be the atmospheric pressure at the steam pipe level. Assume that water fills the two gage connecting pipes to the center line of the steam pipe. If p_1 is greater than p_2, the mercury will rise in the right leg of the differential gage until the hydrostatic pressure is the same at the zero level in both legs. Therefore,

$$p_1 + b \text{ in. mercury} + h_1 \text{ in. water} = p_2 + b \text{ in. mercury} + (h_1 - h) \text{ in. water} + h \text{ in. mercury.}$$

Cancelling common terms, we get for the desired pressure difference:

$$p_1 - p_2 = h \text{ in. mercury} - h \text{ in. water.}$$

At 60 fahr., the ratio of the densities of mercury and water in Table 1 is: One inch water = 0.0737 in. mercury. Hence, the pressure drop is

$$p_1 - p_2 = h \text{ in. mercury} - 0.0737\, h \text{ in. mercury} = 0.9263\, h \text{ in. mercury.}$$

This result shows that the lengths of the connecting pipes do not affect the gage indication provided the water in both pipes has the same density. A considerable error would result, however, by neglecting the fact that the indication is due to the longer column of water in one leg as well as the longer column of mercury in the other leg of the differential gage.

A differential draft measurement would be made by connecting a draft gage as shown in Fig. 2. Let p_1 and p_2 be the gage pressures of the air or products of combustion within the setting at the two points to which the draft gage is connected. Let b inches of mercury be the atmospheric pressure at these two points which are assumed to be on the same level. Assume the two connecting pipes to be filled with atmospheric air above the water in the differential gage. Then,

$$p_1 + b \text{ in. mercury} + h_1 \text{ in. air} = p_2 + b \text{ in. mercury} + (h_1 - h) \text{ in. air} + h \text{ in. water.}$$

The differential pressure is

$$p_1 - p_2 = h \text{ in. water} - h \text{ in. air.}$$

The density of the atmospheric air at 60 fahr. varies from 0.07635 lb. per cu. ft. for dry air to 0.07585 lb. per cu. ft. for moisture saturated air, see article on Humidity of Gaseous Mixtures, *Combustion*, March, 1931; hence, for any relative humidity: one inch of air = 0.0012 in. of water. The differential pressure is accordingly:

$$p_1 - p_2 = h \text{ in. water} - 0.0012\, h \text{ in. water} = 0.9988\, h \text{ in. water.}$$

The coefficient is so near to unity that the effect of air columns may be neglected in differential draft gage readings provided the density of the air in both connecting pipes is the same.

More often, however, a draft gage is connected as shown in Fig. 3 by a single pipe on one side only to one point in the setting where the pressure is desired. Let the pressure within the setting be p_1 above the atmospheric pressure of b inches of mercury at the level of the point of connection. Then,

$$p_1 + b \text{ in. mercury} + h_1 \text{ in. air} = b \text{ in. mercury} + (h_1 - h) \text{ in. air} + h \text{ in. water.}$$

This follows from the fact that the right leg of the draft gage is subjected to a column of air between the level of the water therein and the point of connection in the setting although no pipe is provided as indicated by the dotted lines in Fig. 3. Hence, the gage pressure within the setting is

$$p_1 = h \text{ in. water} - h \text{ in. air} = h \text{ in. water (approx.).}$$

The temperature of the air column above the open leg of the draft gage in Fig. 3 is that of the atmosphere. If the pipe connected to the other leg of the draft gage be run close to a furnace setting, the air therein may have a temperature considerably higher than that of the atmosphere. The two air columns would then have different weights and the draft indication would be affected in proportion to the vertical height of the air columns and their difference in density. While it is better to make the vertical height as short as possible and mount the connecting piping where the temperature is not greatly different from that of the atmosphere because the average temperature within this piping cannot be readily measured, yet corrections can be applied by means of the data in Table 3.

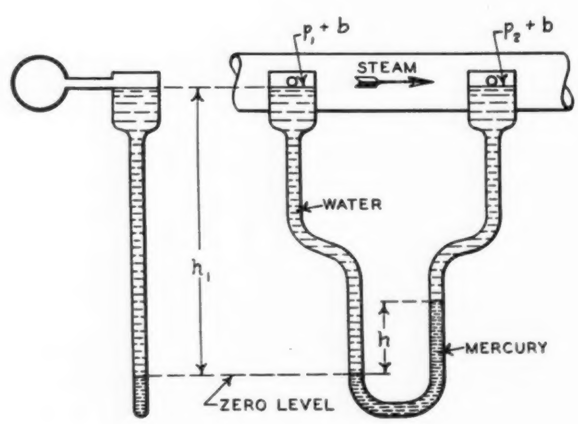

Fig. 1—Mercury differential gage connected to steam pipe.

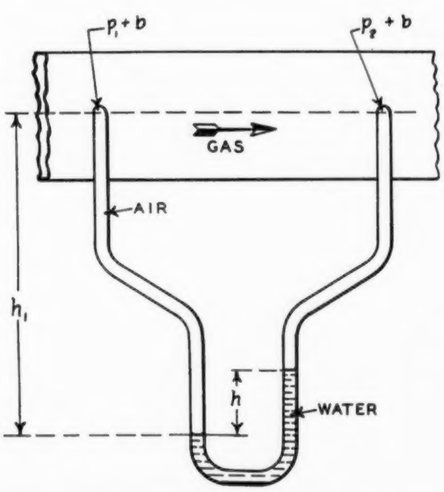

Fig. 2—Differential draft gage connected to setting at two points on same level.

TABLE III—EQUIVALENT INCHES OF WATER COLUMN PER FOOT OF AIR COLUMN UNDER NORMAL ATMOSPHERIC PRESSURE

Temp., fahr.	Volume of one lb.-mole, cu. ft.	Inches of water per ft. of air
0	335.6	0.01650
10	342.9	0.01615
20	350.2	0.01581
30	357.5	0.01549
32	359.0	0.01542
40	364.8	0.01518
50	372.1	0.01488
60	379.4	0.01459
70	386.8	0.01431
80	394.1	0.01405
90	401.4	0.01379
100	408.7	0.01355
110	416.0	0.01331
120	423.3	0.01308
130	430.6	0.01286
140	437.9	0.01264
160	452.5	0.01224
180	467.1	0.01185
200	481.7	0.01149
220	496.3	0.01116
240	510.9	0.01084
260	525.5	0.01054
280	540.1	0.01025
300	554.7	0.00998
320	569.3	0.00973
340	583.9	0.00948
360	598.5	0.00925
380	613.1	0.00903
400	627.7	0.00882

This table contains the numbers of inches of water column at 60 fahr. equivalent to one foot of atmospheric air at temperatures from 0 to 400 fahr. The air was assumed to have 70 per cent relative humidity at 70 fahr., the equivalent molecular weight of which is 28.777 lb. per mole. The volumes in cubic feet of one lb.-mole of any gas were first determined as given in Table 3 by means of the relation

$$v = \frac{359.0}{32 + 459.6}(t + 459.6)$$

where t is the temperature fahr. and 359.0 cu. ft. is the volume of one lb.-mole at 32 fahr. under the normal atmospheric pressure of 29.92 in. of mercury. Dividing 28.777 lb. per mole by v cu. ft. per mole at t fahr. gives the air density at t fahr. Dividing this air density by the density of water at 60 fahr., 0.036092 lb. per cu. in., and by 144 sq. in. per sq. ft., we get the general relation:

$$\text{Inches of water per ft. of air} = 5.537/v$$

which was used to calculate the values in Table 3.

In a certain case, if the atmospheric temperature were 70 fahr. and the average temperature in the connecting piping were 200 fahr. and the draft gage were 40 ft. below the point where the piping enters the setting, the error in indication would be (0.01431 — 0.01149) 40 = 0.113 inch water for normal atmospheric pressure.

In Denver, Colorado, at an altitude of 5291 ft. above sea level, the barometric pressure might be 25 in. of mercury instead of the normal value of 29.92 in. of mercury. The above error for normal barometric pressure would be reduced to 0.113 × 25/29.92 = 0.094 inch of water under the assumed atmospheric pressure at Denver. This calculation illustrates how the corrections for air columns in connecting piping may be modified by variations in atmospheric pressure from the normal value.

Another situation to be considered is where a differential draft reading is taken by means of a single gage connected between two points not on the same level in the setting, as represented in Fig. 4. Let p_1 and p_2 be the gage pressures at the two points, the atmospheric pressure being b_1 and b_2 inches of mercury at these two points respectively. In accordance with the preceding discussion, the two outer gages indicate the pressures p_1 and p_2; that is, approximately $p_1 = h_a$ in. water and $p_2 = h_b$ in. water, so that $p_1 - p_2 = (h_a - h_b)$ in. water. For the middle differential gage, we have,

$$p_1 + b_1 \text{ in. mercury} + h_1 \text{ in. air} = p_2 + b_2 \text{ in. mercury} + (h_2 - h) \text{ in. air} + h \text{ in. water.}$$

Hence, the difference between the pressures P_1 and P_2 is

$$P_1 - P_2 = h \text{ in. water} - h \text{ in. air} + (h_2 - h_1) \text{ in. air} - (b_1 - b_2) \text{ in. mercury.}$$

But the difference in the barometer readings is due to the air column a; hence,

$$(b_1 - b_2) \text{ in. mercury} = (h_2 - h_1) \text{ in. air and}$$
$$p_1 - p_2 = h \text{ in. water} - h \text{ in. air} = h \text{ in. water (approx.)}$$

That is, the differential gage reading h is equal to the difference in the drafts h_a and h_b measured by two draft gages connected to the same two points in the setting. And it should be noted that each draft measurement is the gage pressure within the setting above the atmospheric pressure at that level. The significance of this fact becomes evident when stack effect is discussed.

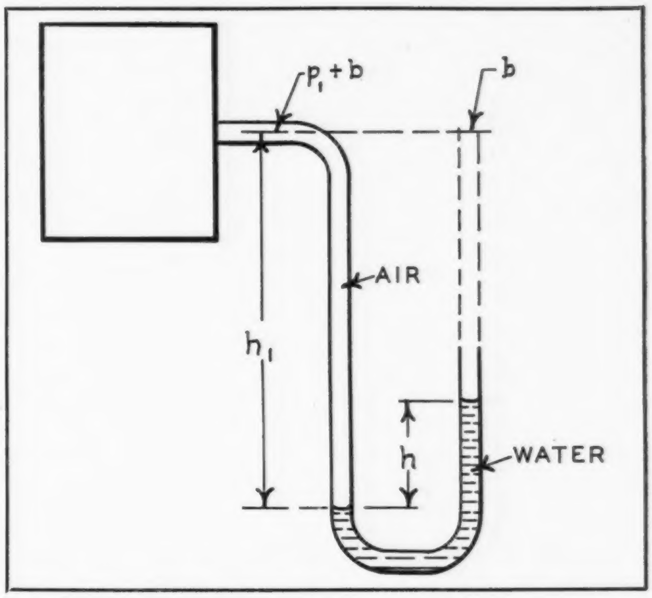

Fig. 3—Draft gage connected to one point in setting.

Leakage in Connecting Pipes

The pressure relations previously derived were based on static columns of air in the connecting pipes between the draft gage and the furnace or boiler setting. Any flow of gas or air through these connecting pipes introduces an error in the gage reading equal to the pressure drop due to frictional resistance to flow. Therefore, the connecting pipes to a draft gage cannot be used for withdrawing a sample of gas from the setting. In fact, great care should be taken to seal against leakage all joints in draft gage piping so that the pressure difference between the atmosphere and the gases with-

in the setting will not produce a flow of air or of gas within the piping between the setting and the point of leakage.

It is sometimes recommended that one-half inch standard iron pipe be used for draft gages instead of smaller size pipe. The object of this recommendation is largely to minimize errors due to leakage. Recently, small copper tubing has been sometimes used by reason of its convenience, special fittings being available for almost any kind of connection desired. To show the necessity of tight joints with this small copper tubing and also to show the relative errors introduced by a given amount of leakage in different sizes of pipes, calculations have been made of the pressure drop corresponding to a flow of 0.2 cu. ft. of atmospheric air per minute through one foot of pipe or tube. This rate of flow would result from a differential pressure of about 0.5 inch of water across a leakage orifice area of 0.01 sq. in. The frictional resistance per foot of pipe or tube between the setting and the point of leakage would be

For ½-inch standard iron pipe, 0.617 inch I.D., 0.001 inch water
For ¼-inch standard iron pipe, 0.360 inch, I.D., 0.013 inch water
For ⅛-inch standard iron pipe, 0.266 inch I.D., 0.053 inch water
For ¼-inch O.D. copper tubing, 0.2 inch I.D., 0.168 inch water.

It is thus evident that great care must be exercised to prevent leakage with small tubes and pipes. Cocks and valves are frequent sources of leakage and may introduce large errors if not inspected carefully.

Shape and Size of Opening in Setting

The draft at any point in a furnace or boiler setting is the static pressure at that point. It is generally agreed that the proper way to measure the static pressure is to install a pipe nipple perpendicular to the inner surface of the wall of the setting with the end of the nipple flush with the surface, all burrs removed and the edges slightly rounded. Sometimes, pipe nipples are not properly installed; and the question arises as to the probable errors in such cases. This problem was investigated by C. G. Knodel in the Technical Research Department of International Combustion Engineering Corporation.

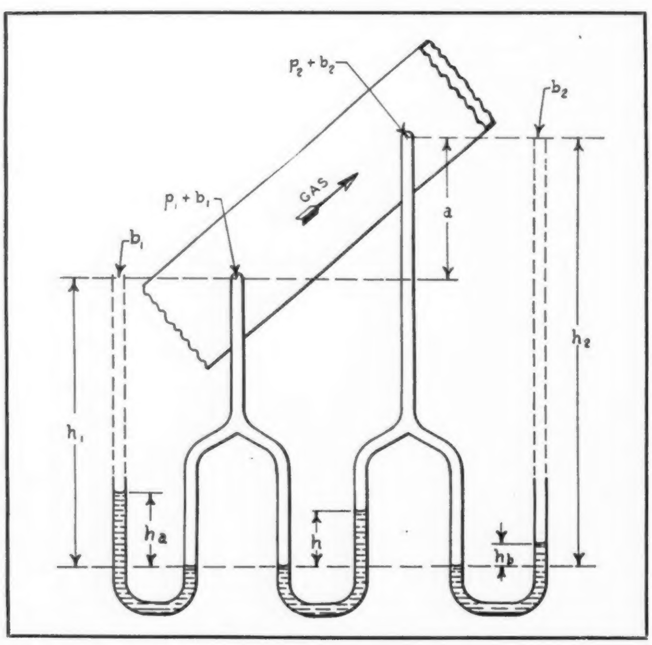

Fig. 4—Differential draft gage connected to two points not on same level.

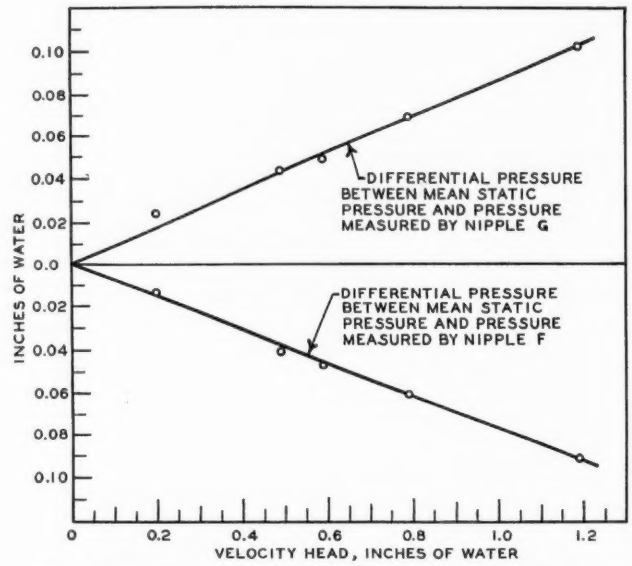

Fig. 5—Errors introduced into draft measurements by improperly installed pipe nipples.

Two ¼-in. pipe nipples were properly installed as explained above in the wall of an 8-in. round pipe. Two other nipples, which will be designated as F and G, were improperly installed. Nipple F had many burrs and protruded about 1/16-in. beyond the inner wall of the pipe. Nipple G was filed off at an angle of about 75 deg. (instead of 90 deg.) to its axis and protruded into the pipe so as to receive the maximum possible impact effect from air flowing through the pipe. All four nipples were mounted around the circumference of the 8-in. pipe in the same cross-section and air was forced through the pipe by a blower. The total impact pressure at the center of this cross-section was measured by an impact tube, that is, a tube bent at right angles with its opening toward the blower so that the indication on the gage to which it was connected would equal the static pressure plus the velocity head as discussed later. The velocity head was taken equal to the total impact pressure minus the static pressure measured by the two properly installed nipples.

The differences between the pressures measured by means of nipples F and G and the average pressure obtained by the two properly installed nipples, were compared with the velocity head for each rate of air flow. As shown by Fig. 5, the apparent static pressure measured by means of nipple F was low by 7.7 per cent of the velocity head while that measured by means of nipple G was high by 9.4 per cent of the velocity head. As nipples F and G represent extreme cases of carelessly installed nipples, it was concluded by Mr. Knodel that with ordinary care in installing nipples for draft measurements, the error in the static pressure indication will be negligible.

There may also be some question as to the size of the nipple to be installed for draft measurements. Mr. Knodel made experimental comparisons between a cop-

per nipple with ¼-in. bore and a ½-in. pipe nipple. This comparison was made in a location affected by eddy currents in the air flow due to a tube bank. The difference in pressures measured with the two nipples was never more than 0.003 in. of water, so Mr. Knodel concluded that the effect of the size of nipple on static pressure can be neglected.

It may be pointed out, however, that care should be exercised in selecting the point of draft measurement as well as installing the pipe nipple. Where the air or products of combustion are caused to change the direction of flow, the nipple should be installed in the wall of the setting which is parallel to the flows before and after the change in direction. In other walls, the static pressure will be increased or decreased by the flow towards or away from the wall. Also, it is desirable to avoid draft measurements within tube banks if possible in order to avoid the errors due to varying velocity head.

Velocity Head

Differences in draft measurements are often directly compared as an indication of the resistances to flow of air or products of combustion between the points of measurement in a furnace or boiler setting. Such comparisons are generally misleading. One reason for this is that the velocity head is generally not the same at the two points of measurement due to a difference in the cross-sectional areas and to a variation in the density of the air or products of combustion. Draft measurements are static pressures and should be increased by the velocity heads at the points of measurement in order to get the total pressures before differences are obtained. These differences should then be corrected for stack effect as will be explained later, before comparisons are made as to relative resistances to flow.

TABLE IV—POUNDS PER MOLE OF PRODUCTS OF CONSTITUENTS OF FUELS FOR COMPLETE COMBUSTION WITHOUT EXCESS AIR

Constituent	Chemical Formula	Molecular weight, lb.
Solids		
Carbon	C	31.255
Sulphur	S	35.396
Gases		
Hydrogen	H_2	24.505
Hydrogen sulphide	H_2S	28.704
Carbon monoxide	CO	33.340
Methane	CH_4	27.569
Ethane	C_2H_6	28.057
Propane	C_3H_8	28.256
Butane	C_4H_{10}	28.364
Pentane	C_5H_{12}	28.432
Ethylene	C_2H_4	28.717
Proylene	C_3H_6	28.721
Butylene	C_4H_8	28.723
Pentylene	C_5H_{10}	28.724
Acetylene	C_2H_2	29.683
Benzol	C_6H_6	29.693
Toluol	C_7H_8	29.529
Solids		
Benzoic acid	$C_7H_6O_2$	30.067
Salicylic acid	$C_7H_6O_3$	30.178
Naphthalene	$C_{10}H_8$	29.949
Sugar (cane)	$C_{12}H_{22}O_{11}$	29.148

The velocity head can be calculated by means of the familiar expression $h = v^2/2g$, where g is the standard acceleration of gravity, 32.1740 ft. per sec. per sec., v is the velocity of the air or products of combustion and h is the velocity head in feet of fluid flowing. But as draft is generally measured in inches of water instead of feet of air or product of combustion, and as the flow of air or products of combustion within a furnace or boiler setting is usually expressed in pounds per hour per square foot of free area instead of feet per second, it is more convenient to use a modified expression. Substituting $h = 0.03609 \times 144 \times p/\rho$ and $v = G/3600\rho$ in the above expression, we get

$$p = 0.0002307\ (G/1000)^2/\rho$$

where G = mass velocity of any fluid in lb. per hr. per sq. ft. of free area,

ρ = density of the fluid in lb. per cu. ft., and

p = velocity head in inches of water.

A further modification of this expression is particularly convenient for air, products of combustion and other gases. Since the volume of one lb.-mole of any gas at 32 fahr. is 359.0 cu. ft. under normal atmospheric pressure and as the volume of a given mass of gas varies approximately in proportion to its absolute temperature under constant pressure, we get for the volume of one lb.-mole of gas at any temperature t fahr. under normal atmospheric pressure:

$$v = 359.0(t + 459.6)/(32 + 459.6)$$

If the gas weighs M lb. per mole, we have for the density under normal atmospheric pressure:

$$\rho = M(32 + 459.6)/359.0(t + 459.6)$$
$$= 1.3694M/(t + 459.6)$$

Whence, the velocity head for any gas under normal atmospheric pressure is

$$p = \frac{0.0001685}{M}(t + 459.6)\ (G/1000)^2$$

where G = mass velocity in lb. per hr. per sq. ft. of free area,

t = temperature, fahr.,

M = molecular weight of gas in lb. and

p = velocity head in inches of water.

For certain common gases, the molecular weight M may be taken from Table 1 in the article on Thermal Properties of a Gaseous Mixture, *Combustion*, February, 1931. For atmospheric air having a relative humidity of 70 per cent at 70 fahr. under normal atmospheric pressure, M = 28.777 lb. per mole. Hence, for atmospheric air, the velocity head under normal atmospheric pressure is

$$p = 0.000005855\ (t + 459.6)(G/1000)^2$$

When combustion of the various constituents of fuels occurs with atmospheric air, the molecular weight of the products varies considerably as indicated by the molecular weights in Table 4 of the products of complete combustion of the constituents of ordinary fuels with the theoretical quantity of atmospheric air having 70 per cent relative humidity at 70 fahr. under normal atmospheric pressure. The solid constituents were assumed to be moisture free while all the gaseous constituents were assumed to be saturated with water vapor at 60 fahr. under normal atmospheric pressure.

As sulphur ordinarily occurs in small amounts only in commercial fuels, we would not expect the products of combustion of commercial fuels to be greatly affected by the high molecular weight of the products of combustion of sulphur with atmospheric air. Solid carbon, however, is the main constituent of most solid fuels and carbon monoxide is a large component of cer-

tain gaseous fuels, while hydrogen occurs as a large component of other gaseous fuels. The large differences in the molecular weights of the products of combustion of carbon, carbon monoxide and hydrogen would indicate quite a range in the molecular weight of the products of combustion of commercial fuels. This range would be augmented by large quantities of moisture or of carbon dioxide in the fuel because the molecular weight of water vapor is 18.015 lb. while that of carbon dioxide is 44.000 lb. On the other hand, the range is reduced by the fact that excess air is nearly always supplied for combustion. The greater the percentage of excess air, the nearer the molecular weight of the products of combustion approaches the molecular weight of atmospheric air, 28.777 lb. with 70 per cent relative humidity at 70 fahr. under normal atmospheric pressure.

As an approximation, which is sufficiently accurate in many cases, the velocity head for products of combustion may be taken equal to that for atmospheric air as given by the formula previously derived. Curves plotted on logarithmic co-ordinate paper in accordance with this formula are straight lines, and are very convenient in picking off the velocity head for any mass velocity and temperature. Also, the velocity head is inversely proportional to the molecular weight of the gas flowing, as indicated by another of the preceding formulas. Therefore, the velocity head is readily obtained for any gas by means of a table of molecular weights, such as Table 5.

Table 5 gives the molecular weights of the products of combustion of the typical fuels in the two articles in *Combustion* for August and December, 1931, entitled respectively "Typical Solid and Liquid Fuels" and "Typical Gaseous Fuels." The molecular weights of products are given for complete combustion with 0, 25, 50 and 100 per cent of excess air having 70 per cent relative humidity at 70 fahr. under normal atmospheric pressure. The corresponding carbon dioxide percentages in the dry products, as would be determined in an ordinary gas analysis, are also given for convenience in applying these data to particular cases. Table 5 will be found convenient for other calculations that will be explained in this and succeeding articles.

If the absolute static pressure of the air or products of combustion differs much from normal atmospheric pressures, as at high altitudes, a correction may be necessary to the velocity head calculated as above explained for normal atmospheric pressure. With the same mass velocity, the velocity head in inches of water varies inversely with the density of the flowing fluid; and as the density of a gas is directly proportional to its absolute pressure, the corrected velocity head is equal to the value calculated for normal atmospheric pressure multiplied by 29.92 in. of mercury and divided by the absolute pressure of the gas in inches of mercury.

Thus, if the mass velocity through a certain cross-section of a furnace setting were 3000 lb. per hr. per sq. ft. of free area and the temperature in the cross-section were 1800 fahr., the velocity head for atmospheric air under normal atmospheric pressure would be

$$p = 0.000005855\ (1800 + 459.6)\,(3000/1000)^2$$
$$= 0.119 \text{ in. of water.}$$

If the fluid flowing were the products of combustion of wet bagasse as fired with 50 per cent excess air, the mole-

TABLE V—MOLECULAR WEIGHT AND CARBON DIOXIDE PERCENTAGE OF PRODUCTS OF COMBUSTION OF TYPICAL FUELS FOR COMPLETE COMBUSTION WITH 0, 25, 50 AND 100 PER CENT EXCESS AIR

		0		25		50		100	
	Typical solid fuels	CO_2	lb./mole	CO_2	lb./mole	CO_2	lb./mole	CO_2	lb./mole
S-1	Dry wood	20.46	29.49	16.34	29.36	13.60	29.27	10.19	29.16
S-2	Seasoned wood	20.42	28.65	16.32	28.68	13.58	28.69	10.17	28.71
S-3	Green wood	20.45	27.31	16.34	27.53	13.60	27.68	10.19	27.92
S-4	Steamed wood	20.36	24.73	16.25	25.19	13.53	25.55	10.14	26.11
S-5	Dry bagasse	20.87	29.37	16.69	29.26	13.90	29.19	10.43	29.09
S-6	Bagasse as fired	20.82	27.03	16.65	27.29	13.86	27.47	10.40	27.74
S-7	Dry tan bark	20.16	29.54	16.09	29.40	13.39	29.30	10.03	29.18
S-8	Tan bark as fired	20.11	25.97	16.05	26.35	13.36	26.62	10.00	27.04
S-9	Pennsylvania anthracite steaming coal	19.84	30.65	15.83	30.28	13.17	30.03	9.85	29.72
S-10	Pocahontas and New River semi-bituminous coal	18.78	30.14	14.94	29.87	12.41	29.70	9.26	29.47
S-11	Pittsburgh bituminous coal	18.67	30.01	14.85	29.77	12.33	29.61	9.21	29.41
S-12	Illinois high-grade bituminous coal	18.53	29.81	14.74	29.62	12.23	29.48	9.13	29.31
S-13	Iowa and Illinois low-grade bituminous coal	18.51	29.76	14.72	29.57	12.22	29.45	9.12	29.28
S-14	Wyoming sub-bituminous coal	19.06	29.40	15.18	29.29	12.61	29.20	9.42	29.10
S-15	Texas lignite	19.01	28.87	15.14	28.86	12.58	28.85	9.40	28.83
S-16	High temperature coke	20.71	31.02	16.56	30.58	13.80	30.28	10.35	29.91
S-17	High temperature coke breeze	20.18	30.57	16.11	30.22	13.41	29.99	10.04	29.69
S-18	Low temperature coke	19.27	30.31	15.35	30.02	12.75	29.81	9.53	29.56
S-19	Wood charcoal	19.78	30.39	15.77	30.07	13.12	29.87	9.81	29.60
S-20	Coal tar pitch	18.92	30.29	15.06	29.99	12.51	29.79	9.34	29.54
S-21	Coal tar coke	19.75	30.66	15.75	30.29	13.10	30.04	9.80	29.73
S-22	Petroleum coke	19.75	30.68	15.76	30.30	13.10	30.05	9.80	29.74
S-23	Rubbish	20.36	29.25	16.26	29.16	13.54	29.11	10.14	29.03
S-24	Garbage	18.05	24.64	14.35	25.12	11.91	25.51	8.89	26.08
S-25	Mixed refuse	19.39	26.43	15.46	26.75	12.85	27.01	9.61	27.36
	Typical liquid fuels								
L-1	Chemically dry methyl alcohol	15.07	27.51	11.88	27.73	9.80	27.88	7.26	28.09
L-2	Methyl alcohol as distilled	15.01	27.29	11.83	27.54	9.76	27.72	7.23	27.96
L-3	Chemically dry ethyl alcohol	15.01	28.07	11.83	28.20	9.76	28.28	7.23	28.40
L-4	Ethyl alcohol as distilled	15.02	27.90	11.84	28.06	9.77	28.16	7.24	28.31
L-5	Coke oven crude tar	18.37	30.01	14.60	29.77	12.12	29.61	9.04	29.40
L-6	Commercial 90-per cent benzol	17.48	29.66	13.86	29.49	11.48	29.37	8.55	29.23
L-7	Commercial tar oil	17.85	29.81	14.17	29.61	11.75	29.47	8.75	29.30
L-8	60-degree A.P.I. gasolene	14.86	28.66	11.71	28.68	9.66	28.70	7.15	28.72
L-9	45-degree A.P.I. kerosene	15.12	28.75	11.92	28.75	9.84	28.76	7.29	28.76
L-10	30-degree A.P.I. gas oil	15.51	28.91	12.24	28.88	10.11	28.86	7.50	28.84
L-11	15-degree A.P.I. fuel oil	15.96	29.09	12.61	29.03	10.42	28.99	7.74	28.94
	Typical gaseous fuels								
G-1	Natural gas	12.02	27.69	9.41	27.89	7.74	28.03	5.71	28.21
G-2	Coal gas	11.55	27.30	9.05	27.56	7.44	27.75	5.49	27.99
G-3	Oil gas	11.67	27.33	9.15	27.59	7.53	27.77	5.55	28.00
G-4	Carburetted water gas	16.55	28.51	13.12	28.56	10.86	28.59	8.09	28.63
G-5	Blue water gas	19.97	28.61	16.00	28.64	13.35	28.66	10.02	28.68
G-6	Producer gas	18.65	29.60	16.03	29.50	14.06	29.42	11.28	29.30
G-7	Blast furnace gas	24.93	31.52	22.31	31.24	20.20	31.00	16.98	30.66
G-8	Oil refinery gas	12.95	28.00	10.16	28.14	8.36	28.24	6.17	28.37

cular weight of which from Table 5 is 27.47 lb., the velocity head under normal atmospheric pressure would be $0.119 \times 28.777/27.47 = 0.125$ in. of water. If the fluid flowing were the products of combustion of blast furnace gas with 25 per cent excess air, the molecular weight of which from Table 5 is 31.24 lb., the velocity head under normal atmospheric pressure would be $0.119 \times 28.777/31.24 = 0.110$ in. of water. If the total pressure were 25 in. of mercury instead of the normal value, the velocity head for atmospheric air would be $0.119 \times 29.92/25 = 0.142$ in. of water.

Measurements in Tube Banks

In boiler tube banks, the mass velocity of the products of combustion through the free area between the tubes is much higher than in the spaces before and after the tube bank. The mass velocity varies from that between the tubes to a much lower value in the spaces between the rows of tubes. There are eddy currents in these spaces, however, which make the calculation of velocity head uncertain. It is advisable not to attempt to measure the draft within a boiler tube bank but to make the measurements in the spaces before and after the tube bank. If a measurement must be made within a tube bank, it is preferable to make the measurement in line with a row of tubes due to the uncertainty of the velocity head calculation at other cross-sections of the setting. Even in line with a tube row, however, the measurement is affected by uneven distribution of flow and by eddy currents which render the reading more or less uncertain.

This point was experimentally investigated by Mr. C. G. Knodel in the Technical Research Department of International Combustion Engineering Corporation. The draft was measured opposite two adjacent rows of staggered tubes near the middle of an experimental tube bank with various rates of air flow through the bank. The measured static pressures were increased by the velocity heads corresponding to the mass velocity between the tubes to get the total pressures. These total pressures were then compared with the values expected from draft measurements made before and after the tube bank under the assumption that the pressure drop was the same from row to row through the tube bank.

For the row of tubes where the last tube in the row was close to the wall of the setting, the total pressure corresponding to the measured draft was less than the expected value by about 28 per cent of the velocity head at all rates of flow. For the adjacent row, where the tube was farther from the wall of the setting, the total pressure corresponding to the measured draft was greater than the expected value by about 45 per cent of the velocity head at all rates of flow. It might be added, however, that the tubes in the experimental tube bank in which these measurements were made, were more closely spaced than would be the case in an ordinary steam boiler, so that the errors in practice would probably not be as great as here indicated. Also, the errors should be less if the tubes are in line rather than staggered from row to row, because the errors for the experimental tube bank are probably due mainly to the rate of flow between the last tube and the wall being materially different from the average rate of flow calculated for the free area between the tubes in the row.

Stack Effect

If the density of the air or products of combustion within the setting of a furnace or boiler were the same as the density of the atmospheric air surrounding the setting, the difference of the draft measurements corrected for velocity heads would equal the frictional resistances to flow encountered within the setting by the air or products of combustion between the points of draft measurement. This would be true because the weight of a vertical column of air or products of combustion within the setting between the points of draft measurement would equal the weight of the atmospheric air column outside the setting.

In this connection, it should be remembered, as explained under air columns in connecting pipes, that the draft measurement at each point is the pressure within the setting above the atmospheric pressure at the same level outside the setting. The atmospheric pressures at two different levels outside the setting differ by the weight of the air column between these levels. The absolute pressures at two different levels within the setting differ by the weight of the column of air or products of combustion between these levels in addition to the frictional resistances to flow. Hence, subtracting the atmospheric pressures from the absolute pressures to get the gage pressures as actually measured, eliminates the effects of the columns of air and products of combustion within and without the setting if these columns have the same density.

In general, however, the density of the air or products of combustion within the setting differs greatly from that of the atmospheric air surrounding the setting. Hence, a correction is necessary for the so-called "stack effect" unless the two points of draft measurement are on the same level.

In case of upward flow within the setting, the stack effect helps to overcome the pressure drop due to frictional resistances, as in the case of any chimney or stack. The weight of the column of air or products of combustion within the setting is then less than the weight of an equal column of atmospheric air outside the setting so that there is a tendency for upward flow within the setting. This upward tendency exists even when the actual flow is downwards. Hence, for downward flow within the setting, the stack effect must be overcome in addition to the frictional resistances to flow.

The magnitude of the stack effect is evidently proportional to the vertical distance between the points of draft measurement and to the difference in densities of the air or products of combustion within the setting and the atmospheric air surrounding the setting. The density of products of combustion is different from that of atmospheric air by reason of differences in molecular weights as previously explained and as shown in Tables 4 and 5. The main reason for the difference in density, however, is the high temperature of the products of combustion within a furnace or boiler setting as compared with that of the atmosphere outside. The difference in pressures within and without the setting is seldom sufficient to make an appreciable difference in density. If the atmospheric pressure differs much from the normal value of 29.92 in. of mercury, a correction is necessary for stack effect calculated on the basis of normal atmospheric pressure.

In order to calculate stack effect, it is convenient to have tables or curves giving the inches of water column at 60 fahr. equivalent to a one-foot column of different gases at a series of temperatures within the range met in practice. An inspection of Table 5 shows that products of combustion of commercial fuels have molecular weights between 24 and 32 lb. Table 6 was accordingly prepared to give the inches of water at 60 fahr. corresponding to one foot of gases having molecular weights from 24 to 32 lb. and temperatures from 0 to 3000 fahr. A set of values was included for atmospheric air having a molecular weight of 28.777 lb. for 70 per cent relative humidity at 70 fahr. under normal atmospheric pressure.

The values in Table 4 were calculated by means of the relation

Inches of water at 60 fahr. per foot of gas at t fahr. under normal atmospheric pressure $= \rho/(0.036092 \times 144)$

$= (32 + 459.6)M/(t + 459.6)359.0 \times 0.036092 \times 144$

$= 0.2635M/(t + 459.6)$

where t = temperature of gas, fahr.,

M = molecular weight of gas, lb., and

ρ = density of gas under normal atmospheric pressure at t fahr., lb. per cu. ft.

For atmospheric air under normal atmospheric pressure,

Inches of water at 60 fahr. per foot of air at t fahr. $= 7.582/(t + 459.6)$

For example, consider the case where products of combustion of blast furnace gas burned with 25 per cent excess air flow upwards through a tube bank. The static draft measurement before entering the tube bank is minus 0.75 in. of water. The draft after leaving the tube bank is minus 1.33 in. of water at a level 24 ft. above that of the first draft measurement. The average temperature within the tube bank is 1000 fahr. The velocity heads before entering and after leaving will be taken as 0.07 and 0.05 in. of water respectively.

$-1.33 + 0.07 = -1.26$ in. water total draft entering
$-0.75 + 0.05 = -0.70$ in. water total draft leaving

0.56 in. water difference in total drafts.

1 ft. air at 70 fahr. = 0.01431 in. water from Table 3.
1 ft. gas at 1000 fahr. = 0.00564 in. water from Table 4.

0.00867 in. water difference.

$0.00867 \times 24 = 0.208$ in. water stack effect.
$0.56 - 0.21 = 0.35$ in. water frictional resistance.

The apparent resistance to flow through the tube bank is $1.33 - 0.75 = 0.58$ in. water, which is about 66 per cent in error.

The smaller the frictional resistances and the higher the temperatures within the setting, the more misleading is the apparent resistance to flow found by subtracting the draft measurements.

It may be noted that it would generally be sufficiently accurate to determine the stack effect under the assumption that the products of combustion within the setting have the same density as atmospheric air would have at the same temperature. That is, a single curve plotted from the values in Table 6 for the molecular weight of 28.777 lb. would generally serve for this calculation. It may be necessary, however, to modify the value for the low atmospheric pressures encountered at high altitudes. Thus, if the barometric pressure were only 25 in. of mercury instead of the normal value of 29.92 in., the stack effect in the above example would be reduced to $0.208 \times 25/29.92 = 0.174$ in. of water.

TABLE VI—INCHES OF WATER AT 60 FAHR. EQUIVALENT TO ONE FOOT OF GAS

Temp., fahr.	Molecular weight, lb. 24	26	28	28.777	30	32
0	0.01376	0.01491	0.01605	0.01650	0.01720	0.01834
100	0.01130	0.01224	0.01318	0.01355	0.01412	0.01507
200	0.00959	0.01039	0.01118	0.01149	0.01198	0.01278
300	0.00832	0.00902	0.00971	0.00998	0.01041	0.01110
400	0.00736	0.00797	0.00858	0.00882	0.00920	0.00981
500	0.00659	0.00714	0.00769	0.00790	0.00824	0.00879
600	0.00597	0.00647	0.00696	0.00716	0.00746	0.00796
700	0.00545	0.00591	0.00636	0.00654	0.00682	0.00727
800	0.00502	0.00544	0.00586	0.00602	0.00628	0.00669
900	0.00465	0.00504	0.00543	0.00558	0.00581	0.00620
1000	0.00433	0.00469	0.00505	0.00519	0.00542	0.00578
1200	0.00381	0.00413	0.00445	0.00457	0.00476	0.00508
1400	0.00340	0.00368	0.00397	0.00408	0.00425	0.00453
1600	0.00307	0.00333	0.00358	0.00368	0.00384	0.00409
1800	0.00280	0.00303	0.00326	0.00336	0.00350	0.00373
2000	0.00257	0.00279	0.00300	0.00308	0.00321	0.00343
2200	0.00238	0.00258	0.00277	0.00285	0.00297	0.00317
2400	0.00221	0.00240	0.00258	0.00265	0.00276	0.00295
2600	0.00207	0.00224	0.00241	0.00248	0.00258	0.00276
2800	0.00194	0.00210	0.00226	0.00233	0.00242	0.00259
3000	0.00183	0.00198	0.00213	0.00219	0.00228	0.00244

Conclusions

Draft measurements are usually inaccurate. It is rather the exception than the rule that reliable calculations can be made from them of the frictional resistances to flow through furnace and boiler settings. The reason is that the pressures are very low so that they are subject to disturbing factors which have but little influence on the measurements of moderate and high pressures. Often draft measurements are true only to one-tenth of an inch of water while the resistance through the tube bank amounts to but several hundredths of an inch.

The present article discusses the various factors which affect the accuracy of draft measurements and the corrections which must be applied in interpreting the results of such measurements. The effect of pulsations in the flow of air or products of combustion upon the accuracy of draft measurements has not been touched upon as this subject is now being studied by a committee of the American Society of Mechanical Engineers. A future article will discuss the frictional resistances encountered by air and products of combustion in flowing through furnace and boiler settings.

The Superheater Company announces that on May 1, 1933, its Pittsburgh office, formerly located in the Union Trust Building, will move to the American Bank Building, 600 Grant Street. The office will remain in charge of R. L. Ehmann, representing the Industrial Department in the sale of Elesco superheaters for stationary boilers, separately fired superheaters and other heat exchange apparatus for stationary power plants.

Droughts and Their Influence on the Quality of Water for Industrial Uses*

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Consulting Chemical Engineer

Baltimore, Maryland

Very little information has been published on this subject, the importance of which has not been generally realized. The author presents a thorough discussion of it much of which pertains to the effects of droughts on boiler feedwater. He makes it apparent that proper analytical study of feedwater sources, prior to the installation of treatment apparatus, may save much money and grief especially where such sources are subject to marked influence as a result of drought conditions. The requisite data for such studies are indicated.

THE customary statistical definition of a drought indicates a period of twenty days or more with rainfall in any twenty-four hours not exceeding one-quarter of an inch or the amount of monthly rainfall expressed in percentage below the normal. The first case requires available daily records of precipitation but since these have only been recorded in recent years, earlier conditions may be indicated by deviations from average percentages in respect to monthly precipitation records. There are sufficient records, however, to demonstrate the relative duration and intensities of extreme dry periods throughout the country and such records are invaluable indices for predicting not only the quantity but the relative quality of water supplies. Weather bureau statistics show that within the last fifty years there have been five important droughts. These extreme dry periods have been similar in respect to the area of the country affected and in the degree of deficiency from normal annual precipitation. Since 1894, four major droughts have occurred in this country and numerous other periods of deficient rainfall in restricted areas. The magnitude and intensity of the major droughts are indicated in Table I.

During droughts there is not only a marked diminution in run-off of surface streams and a reduction in the availability of ground water, but the chemical composition of all water resources is greatly affected. These conditions greatly depreciate the value of water for industrial uses and have a marked influence on the type of purification system which should be installed. Little consideration has been given to these important factors with the result that great inconvenience is frequently experienced.

The drought of 1930-1931 is still vivid in the minds of many persons and has focused attention on the need for intensive study of hydrographic records in order to avoid future failures of industrial water supplies and breakdown in water treating systems. While the 1930 drought was in progress, human distress in certain sections of the country was so great that the industrial difficulties encountered during the period, received little public attention. It is natural, and rightly so, that the industrial aspects of such a calamity should be secondary to that of human suffering. The depreciation in the quality of water supplies so affected was very marked, however, and the economic losses occurring were enormous. It is impossible to evaluate or compute, accurately, such losses but there are certain phases of the problem subject to individual analyses and tangible and calculable losses sustained by the industries may be clearly demonstrated from the operating records available.

The potential value of any water used for industrial purposes is affected greatly by the presence of hardness, chlorides, organic matter or other constituents. The magnitude of the changes occurring in the mineral content of a water during droughts is dependent upon the geological formations of water sheds, domestic and trade waste pollution of the streams and the proximity of such streams to tidal waters. The composition of water in all the larger rivers in the drought area during 1930 and extending to 1931 was so affected and since industrial activity, generally, is most concentrated along these water courses, great inconvenience and financial losses occurred.

Variation in the chemical composition of the Delaware River water during the years in question is characteristic of conditions elsewhere where reduced river flows occurred. The effect of run-off upon the mineral content of this water is illustrated in Fig. 1. This graph indicates the increase in the hardness of the river water resulting from decreased river flows. The figures reported are averages for many hundred analyses, taken at sampling stations established on the Delaware River near Easton, Pennsylvania, a short distance below where the Lehigh River enters the Delaware River and at Brammel's Point, New Jersey, located a few miles below Philadelphia. The river at this latter station is influenced by the waters of the Schuylkill River since the sampling station is located at a point below

where the Schuylkill enters the Delaware River. The highest hardness occurring in the water, shown on the extreme lower portion of the curve, indicates the drought periods covering the latter part of 1930 and early in 1931. The rise of hardness in the water in the Delaware at points lower down the river was even more marked than for the stations reported. It must be apparent that so wide fluctuations in the chemical composition of the water, as indicated by changes in hardness, will be reflected to a marked degree in the operation of feedwater treating systems supplying steam generating stations and in many other industrial plants requiring completely softened water.

Effect of Salinity on the Design and Operation of Boiler Feedwater Purification Processes

The difficulty experienced during droughts is greatly magnified whenever the run-off of surface water streams is so reduced as to permit influx of seawater. Many fresh water streams were so affected during the recent drought period and salt water contamination of these rivers occurred many miles up stream. Where properly designed water conditioning plants were not available and where precautions against these conditions had not been taken, great losses occurred in attempting to continue operations. In some sections the conditions were so severe as to require the closing of many industrial plants.

TABLE I *

DEPARTURES FROM NORMAL PRECIPITATION IN DROUGHT YEARS 1894, 1895, 1910, AND 1930, IN INCHES **

District	1894	1895	1910	1930
New England	— 8.1	— 5.3	— 6.7	— 7.6
Middle Atlantic States	— 5.3	— 9.1	— 5.5	—12.8
South Atlantic States	— 4.2	— 3.7	— 9.0	— 9.3
East Gulf States	— 9.0	— 8.6	— 7.6	— 4.8
West Gulf States	— 6.8	— 6.7	— 7.8	— 2.9
Ohio Valley and Tennessee	—11.0	—11.0	— 1.2	—13.4
Lower Lake Region	— 4.5	— 5.8	— 5.9	— 6.5
Upper Lake Region	— 2.0	— 7.1	— 6.5	— 9.3
North Dakota	— 0.5	— 1.1	— 8.0	— 3.5
Upper Mississippi Valley	—12.0	— 7.8	— 9.8	— 6.8
Missouri Valley	— 8.8	— 2.9	— 5.0	— 4.5
Northern slope	— 1.4	— 0.4	— 3.0	— 0.9
Middle slope	+ 0.4	— 1.6	— 7.7	— 0.4
Southern slope	— 3.7	+ 7.2	—12.2	— 0.9
Southern plateau	— 3.9	+ 0.4	— 3.5	— 1.0
Middle plateau	+ 0.2	— 2.6	— 3.7	+ 0.3
Northern plateau	+ 0.9	— 4.5	— 1.5	— 1.9
North Pacific	+11.7	— 4.1	— 2.3	—12.6
Middle Pacific	+ 1.8	— 5.6	—10.9	— 7.5
South Pacific	— 4.6	— 4.4	— 7.1	— 1.0
Percentage of area of non-arid States in which precipitation was deficient	54.3	44.5	50.4	55.9

* John C. Hoyt, Hydraulic Engineer, United States Geological Survey, Washington, D. C.—"The Drought of 1930."—Journal American Water Works Association, Vol. 23, No. 11, November, 1931, page 1826.

** Normal precipitation determined from data available at the dates indicated.

The reduced quality of boiler feedwater during these periods had far greater effect during the recent drought than would have occurred a few years ago. The recent radical changes in the design and operation of steam generating stations require the highest quality of feedwater and, relatively satisfactory circulating water for condenser use. At generating stations where a large percentage of the steam is condensed and returned to the system, the use of evaporators for treatment of the make-up water is possible, since the water requirements under such conditions are relatively small and the cost of installation of evaporating equipment is not prohibitive. At many steam generating stations, however, and in the majority of industries requiring relatively large quantities of steam for process work, little or no condensate is returned to the boilers. Under such conditions a high percentage of make-up is required so that evaporators may not be economically used. To prepare a satisfactory feedwater for the latter condition, softening by chemicals or other processes is necessary. The contamination of fresh water supplies by salt or brackish water increases, not only the sodium chloride (salt) in the water so contaminated, but results also in proportional increases in scale forming salts. It is evident that such contamination may greatly overtax the design capacity of the purification system and markedly increase the cost of operation unless provision has been made in the design of the treatment works to cope with the changes in the chemical composition of the water which has been so contaminated.

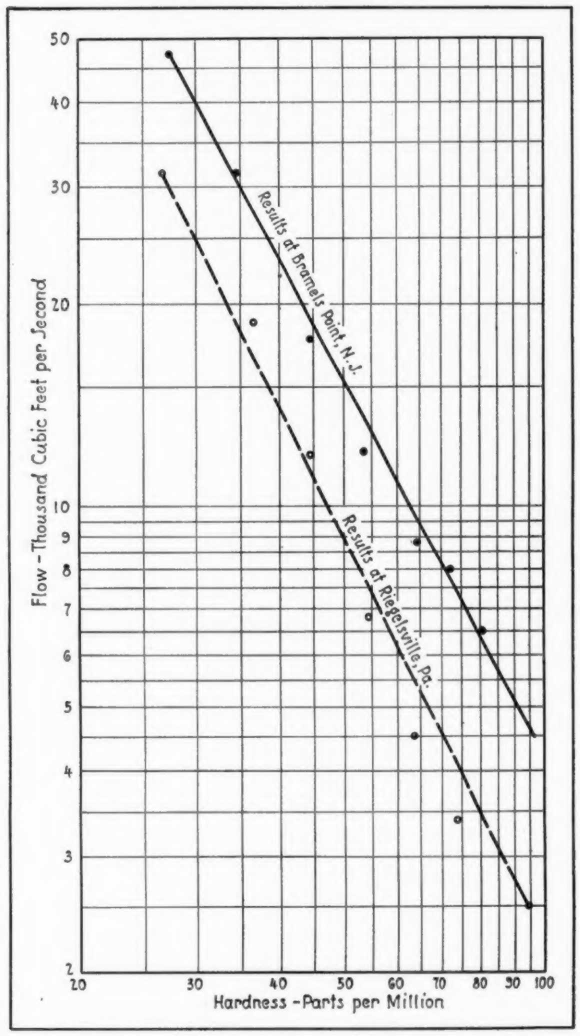

Fig. 1—Chart showing increase in the hardness of Delaware River water resulting from reduced river flows during drought conditions.

The magnitude in the contamination resulting from influx of seawater into a fresh water supply is graphically illustrated in Fig. 2, showing the concentration of total solids and sodium chloride present in the Delaware River water in December, 1930, during extreme drought conditions as compared with samples of water taken in April, 1931, after the drought was terminated. These samples were taken at a point between Philadelphia and Chester on the New Jersey side of the river and represent samples collected during a complete tide cycle in each case.

Change in the chemical composition of water of so

large a magnitude greatly increases the cost of operation of softening systems and even under the most careful operation, makes complete purification difficult. As an illustration of the reduction of water softening occurring, there is shown in Fig. 3 the effect of high sodium chloride from seawater contamination on zeolite water softening minerals. It will be noted from this graph that the extreme rise in salt and hardness of the untreated water was followed by erratic performance in the removal of scale forming solids; also, that during the period noted the softening system was incapable of delivering satisfactory water with respect to the removal of hardness even under the most intelligent and careful operation of the system. Softening water for industrial uses by base exchange minerals (zeolites) is practiced widely and has a specific field of usefulness under certain conditions. The efficacy of such water purification systems will depend upon a number of factors, the hardness and chloride content of the water being of major importance. As the hardness and salinity increases above certain concentrations the softening efficiency of the mineral is reduced. The effect of chlorides on the exchange capacity, namely, the softening capacity of a given quantity of zeolite mineral, is fairly well recognized and where wide fluctuations in these constituents are anticipated, manufacturers of such equipment qualify guaranteed performance in accordance with the predicted salt content of the raw water supply. Equipment, purchased under these conditions, is subject to performance guarantees and is based on what is known currently in the profession as "compensated hardness." The latter phase is indicative of anticipated reductions in softening efficiency of softening mineral resulting from high concentrations of sodium salts in the untreated water.

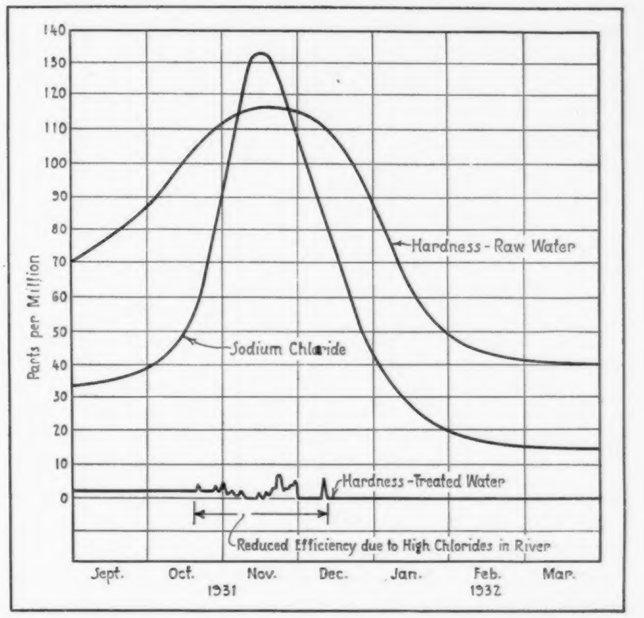

Fig. 3—Chart showing reduction in softening efficiency of zeolite mineral resulting from high sodium chloride in the raw water.

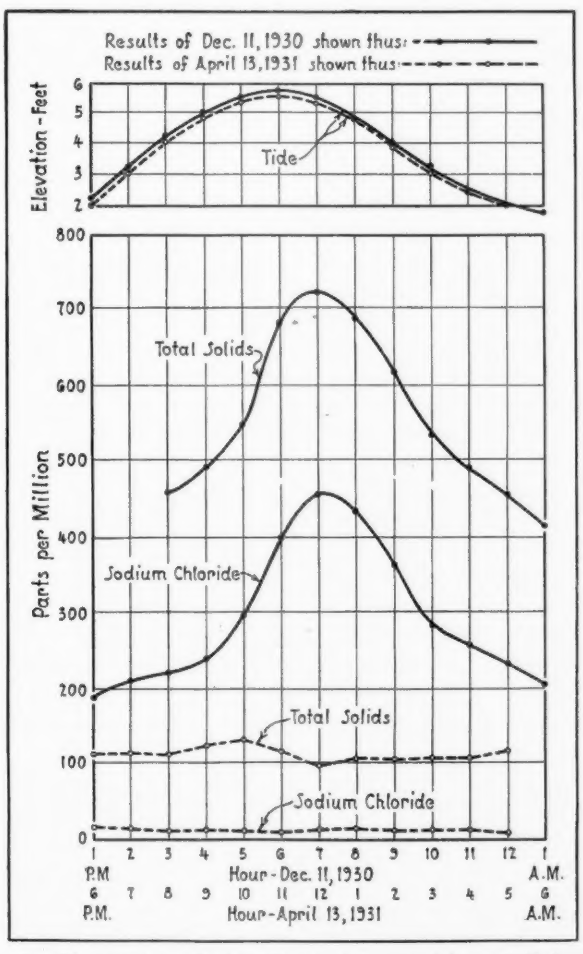

Fig. 2—Fluctuation of the chemical composition of Delaware River water resulting from the influx of salt water during periods of reduced river flow. Samples taken at Brammel's Point, New Jersey. River flow at Trenton, New Jersey, December 11, 1930—3190 cu. ft. per sec. and on April 13, 1931—29,500 cu. ft. per sec.

The marked effect of salt water contamination during drought periods on the softening capacity of zeolite mineral has been calculated and reported in Fig. 4. Reference to this chart shows that when the water under treatment contains ten grains of hardness and less than ten grains per gallon of sodium chloride, a cubic foot of zeolite mineral will soften slightly less than 300 gallons of such water, while if the sodium chloride content is raised to sixty grains per gallon the softening capacity of the mineral is reduced by about one-half. This clearly demonstrates that in the design of such systems consideration should be given to the potential possibilities of salt water contamination in order to adequately design treatment plants which will have ample capacity during dry weather periods. Unfortunately, little consideration has been given to these design factors and many plants installed had insufficient capacity when required to soften water subjected to sea water contamination.

Influence of Drought on Cost of Operation of Boilers

The percentage of blowdown water, required for safe operation of boilers, increases greatly as the concentration of solids in the feedwater supply increases. The financial losses sustained by wasting large volumes of hot boiler water may become excessive. Estimated losses which are possible under a specific set of conditions are shown in Fig. 5. Such losses can be minimized by the installation of heat exchangers on the blowdown line and the utilization of the heat from the blowdown boiler water for feedwater heating or for

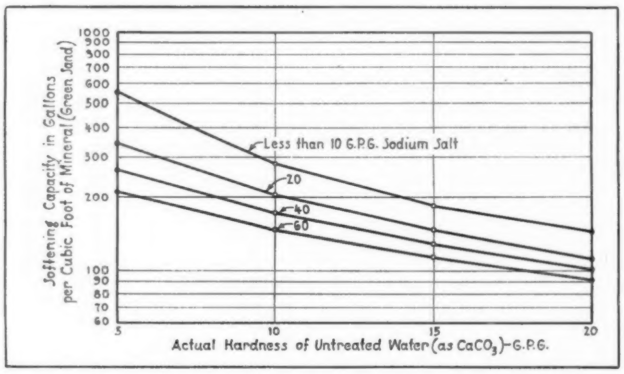

Fig. 4—Chart showing the reduced performance of softener units due to increased sodium chloride content of the raw water.

other uses permissible with the existing heat balance of the station. The economy resulting from such heat recovery will be dependent upon the investment required for the installation of the necessary apparatus and other incidental costs. Even where the design of the specific steam station permits economic heat recovery from the blowdown water, certain losses will still exist, since complete utilization of heat from this source is not possible. There are, also, appreciable losses due to the volume of the blowdown water which must be wasted. Notwithstanding the possible control of the concentration of boiler water salines by the installation of continuous blowdown and heat recovery appliances after the station has been built, consideration should be given to the possible wide fluctuation of the chemical composition of feedwater during drought periods, since it is frequently difficult to economically control the situation after a station has been designed and constructed. Much difficulty may be avoided if the predicted conditions are taken into consideration initially and provision is made in the plant design to cope with these critical conditions as they arise.

Effect of Sewage and Trade Wastes on the Quality of Water Supplies During Droughts

The majority of surface water courses, in highly industrialized centers, are subjected at all times to contamination from industrial wastes and domestic sewages from numerous communities. During normal river flows such contamination, except under extreme conditions, may have no serious effect on the value of industrial water supplies. During periods of extreme reduction in run-off, stream pollution becomes a matter of great importance and in many cases results in critical operating conditions. The reduction in adequate quantities of water to dilute the polluting substances discharged into streams greatly increases the organic content of the water, fosters the prolific growth of microscopic plant life, increases the mineral content of the water and imposes other penalties on the users of industrial water supplies. The severity of the 1930 drought demonstrated the limited capacity of many rivers with respect to the sewage loads placed on streams in industrial centers. There were numerous cases where the dissolved oxygen in the water was completely exhausted resulting in the creation of putrescible conditions and the production of hydrogen sulphide and other products of decomposition.

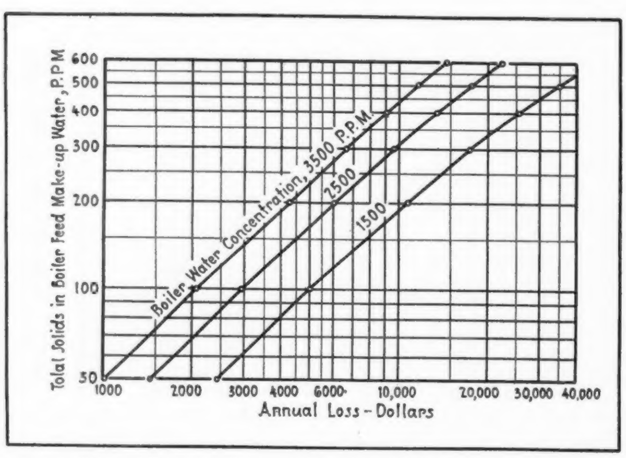

Fig. 5—Chart showing annual loss resulting from blowing down boilers without heat recovery. Losses estimated upon fuel at \$5.00 per ton and evaporating 100,000 lb. of water per hr. under 400 lb. pressure. Boilers operated 75 per cent of the year and boiler efficiency at 75 per cent. (Figures do not include value of water wasted and other incidental losses).

In one central station on the Eastern seaboard, great difficulty was experienced in the prevention of organic slimes in surface condensing apparatus. Coagulation, filtration and softening of many waters was so affected that prevention of scale formation was practically impossible. The corrosive properties of water supplies under these conditions was also greatly increased, making corrective treatment difficult and costly.

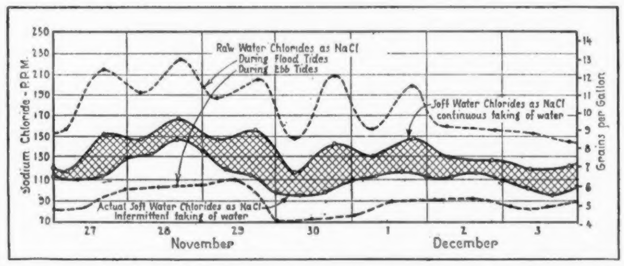

Fig. 6—Chart showing reduction in the sodium chloride content of a boiler feedwater supply resulting from selective taking of Delaware River water during drought periods.

The most important factor in providing for water supplies of good quality during drought periods is a collection of adequate analytical data over a long period and provision in the design of the purification system which will permit satisfactory treatment under widely fluctuating conditions.

There is a tendency to design boiler feedwater treating systems based on the analyses of "grab" samples of waters or averages of a relatively few samples collected over a short period of time. Where the water supplies are drawn from large inland bodies of water, not influenced by seasonal variations, such a procedure is relatively satisfactory. Where the water supply is taken from rivers and when there are wide deviations in the chemical composition, careful analyses and interpretations of the assembled data are desirable. Such analytical data are not always available but generally much information can be acquired by recourse to Federal, State and Municipal records. It is especially important to study the geological features of the water sheds contributing to the particular water course under consideration. The factors involved in such a survey should include:

1—The topographical features of the main and secondary water sheds.
2—Stream flow records.
3—Character of geological formation and soil conditions of the catchment areas.
4—Precipitation statistics over long periods and a critical interpretation of rainfall records during droughts.
5—Tidal conditions and rise of salinity resulting from influence of seawater.
6—A comprehensive study of surface and underground water supplies including a critical study and interpretation of the relative values of such supplies when employed alone or in combination with river water.

It must be apparent that the collection and intelligent interpretation of the foregoing data will be of the greatest assistance in designing adequate water conditioning processes. Under conditions where sea-water contamination of the fresh water supplies during drought periods is indicated, the degree of the contamination may be greatly reduced by intermittent and selective pumping, and storing of the water in holding tanks or reservoirs. A marked reduction in the chlorides and total solids in the water is possible by such operation. The actual reductions effected at one plant during extreme drought conditions, have been plotted and are shown graphically in Fig. 6. At this particular plant the incoming or flood tides resulted in greatly increasing the salt content of the water, while during outgoing tides the brackish water was flushed out by the fresh water flowing in the river. By operating the river pumps for only a few hours a day and storing the less contaminated water, a marked saving in the operation of the boiler feedwater treating system was effected. The cost of the installation of the storage reservoirs and the auxiliary equipment necessary for this method of operation has been fully justified by the saving resulting therefrom. It frequently happens that both surface water supplies and well waters are available, and, where such conditions exist, admixture of the two waters in various proportions is advantageous during extreme droughts for limiting the mineral content below that which would occur by the use of either supply alone. At times relatively large quantities of condensate are wasted due to the fact that they are contaminated by oil or other foreign matter. The purification of such water is often justifiable and may be highly desirable for diluting the more highly contaminated water used as a primary water supply. Generalization in reference to adequate and satisfactory treatment of industrial water supplies is questionable, since there are many factors influencing the ultimate decision as to the best form of treatment. The final decision should rest upon an engineering study and allocation of all contributing factors.

The urgency for comprehensive studies as outlined is not generally recognized. Trends in industrial expansion and the more intensive steam station operating conditions, however, are directing attention to the necessity for such action. These viewpoints, although limited to a small group of engineers, are resulting in elevating the art of water purification for industrial purposes into a highly specialized field. To such a group, industrial waters are viewed as engineering materials, subject to manufacture and control in accordance with definite specification, the severity of which depends upon the degree of purification required for their specific uses.

New Tentative Standard Grain Size Chart for Classification of Steels Now Available

The new tentative standard grain size chart for classification of steels (E 19-33 T) has just been published. This was recently approved for publication as a tentative standard by the Standards Committee on the recommendation of A. S. T. M. Committee E-4 on Metallography.

The need of grain size determinations for S. A. E. and allied steels has been quite generally recognized. Many laboratories are making these tests and as a result different grain size classifications have been in use with resulting confusion in the discussion of grain size. The new tentative standard is the result of laboratory experience extending over a period of ten years, and a proposed standard has been in the hands of Committee E-4 for about two years.

Copies of this chart may be purchased from the American Society for Testing Materials, 1315 Spruce St., Philadelphia, Pa. The cost for single copies is 25 cents. On quantity orders, special prices will be quoted.

The Patterson Foundry & Machine Company, East Liverpool, Ohio, announces the appointment of Mr. R. C. Denny as Chief Engineer of their Stoker Division.

Mr. Denny is well known to the engineering fraternities through his identity with stoker and furnace work during more than fifteen years with the Combustion Engineering Corporation of New York, and the M. H. Detrick Company of Chicago. His experience has included work with all types of stokers from multiple retort and chain grates to domestic sizes, as well as special work in furnace design and various fuels.

A. S. H. V. E. to Meet in Detroit

The program for the semi-annual meeting of the American Society of Heating and Ventilating Engineers, to be held at Hotel Statler, Detroit, Mich., June 22 to 24, 1933, will be in charge of the Michigan Chapter, and the chairman of the General Arrangements Committee is L. L. McConachie. Registration will commence at 8:30 A. M. on Thursday on the ballroom floor of the Hotel Statler. The meetings will be held on Thursday, Friday and Saturday, and each morning will be devoted to technical discussions while the afternoons and evenings have been reserved for golf, sightseeing inspection trips, banquet and other entertainment features.

Draft Losses in Steam Plants*

By J. G. MINGLE Indianapolis, Indiana

This article begins with a theoretical discussion of draft loss and gives a general formula, based on Bernouilli's Theorem, which is broadly applicable to steam plant installations. The author then discusses and gives formulas for the determination of the various separate draft losses which comprise the total loss through a steam generating unit. The discussion of the different losses is interspersed with comments on their nature, the factors entering into them and the effects of these factors on draft loss. For example, in considering draft losses through breechings the author discusses the relative effects of velocity and friction with respect to breeching design and tells how breechings should be designed to balance these factors.

A KNOWLEDGE of the effects of the flow of gases and water is of great importance in steam plant practice since the problem of the removal of gases from the furnace and the delivery of water to the boilers is encountered in all installations. This problem involves the pressure drops through the installation and the head necessary to maintain the fluid flow. While the fluid velocities of the gases and water are comparatively low and the pressure drops are of relatively low intensity as compared with the flow of steam in pipes, yet, in order to determine the amount of head which must be developed by the pressure transformer, that is, the draft producing system or pumping system, it is necessary to know the intensities of the various pressure drops throughout the entire path of the fluid stream. Draft losses due to the flow of air and gases from the furnace entrance to the top of the chimney are comparable with the head losses due to the flow of water from the suction end of the pump to the boiler.

The solution of problems involving the flow of fluids in ducts is based on Bernouilli's Theorem and can be approached from two angles, viz:

1. The law of the conservation of energy
2. The mechanical energy balance.

The equation for the mechanical energy balance, the more commonly used equation of the two, when the fluid is at rest may be written as follows:

$$h'_p + h'_s + h'_v + \int pdv = h''_p + h''_s + h''_v \qquad (1)$$

in which h_p = potential head
h_s = pressure head
h_v = velocity head
$\int pdv$ = work done by the expansion of the fluid upon itself.

The potential head is the vertical distance above the datum plane; the pressure head, the head exerted on a plane parallel to the direction of flow; and the velocity head, the head exerted on a plane perpendicular to the direction of flow less the pressure head. The various heads may be measured in terms of lb. per sq. in. by means of a pressure gage, in. of mercury by means of a mercury gage, or in. of water by means of a U-shaped water gage.

When applied to the case of gases in motion and flowing freely in a steam plant installation, equation (1) may be written as follows:

$$D_t - h_f = h_F + h_B + h_{Br} + h_{Bd} + h_{En} + h_C + h_E + h_R + h_V \qquad (2)$$

in which D_t = theoretical draft developed by the pressure transformer, in. of water
h_f = draft loss due to friction in pressure transformer in. of water
h_F = draft loss through the furnace and fuel bed, in. of water
h_B = draft loss through the boiler and setting, in. of water
h_{Br} = draft loss through the breeching, in. of water
h_{Bd} = draft loss due to turns and bends, in. of water
h_{En} = draft loss through the economizer, in. of water
h_C = draft loss due to abrupt contraction, in. of water
h_E = draft loss due to abrupt enlargement, in. of water
h_R = draft loss through regenerators and recuperators in. of water
h_V = draft loss due to velocity, in. of water.

The left hand member of equation (2) represents the total amount of available draft created by the pressure transformer, that is, the natural-draft chimney, blower or exhauster, and is equal to the theoretical intensity developed less the internal losses incidental to operation. The right hand member represents the sum of all of the various draft losses throughout the entire steam plant installation outside of the pressure transformer itself and which the pressure transformer must overcome in order to maintain a gas flow. The left hand member expresses the available intensity and is analogous to the head developed by a centrifugal pump in water works systems while the right hand member expresses the required draft intensity and is analogous to the total dynamic head in a water works system.

The general draft equation can be applied to any steam plant installation regardless of the type of draft producing system used. For a general circulation of the gases, equation (2) may be shortened as follows:

$$D_a = D_r \qquad (3)$$

in which D_a = available draft developed by the pressure transformer, in. of water

D_r = required draft of installation, in. of water.

Draft Loss Through the Fuel Bed

The draft loss through the fuel bed (h_F), or the required amount of draft necessary to effect a required rate of combustion, varies between wide limits and represents the greater portion of the total draft loss. In coal fired installations, the draft loss through the fuel bed is affected by the following:

1. Character and condition of fuel
2. Percentage of ash in the fuel
3. Volume of interstices in the fuel bed
4. Thickness of fuel bed
5. Type of grate, or stoker, used
6. Efficiency of combustion.

There is a certain intensity of draft with which the best results will be obtained for each and every kind of coal and rate of combustion. Fig. 1 gives the draft intensity, or vacuum in the combustion chamber, required to burn various kinds of coal at various rates of combustion. Expressed in other words, these curves represent the amount of draft required to force the necessary amount of air through the fuel bed to effect various rates of combustion. It will be noted that the amount of draft required increases as the percentage of volatile matter diminishes, being comparatively low for the lower grades of bituminous coals and highest for the high grades and small sizes of anthracites. Also, when the interstices of the fuel bed are large and the coal particles are not well broken up, as with bituminous coals, less draft is required than when the particles are small and are well broken up as with the bituminous slack and the small sizes of anthracites. In general, the draft loss through the fuel bed increases as:

1. The percentage of volatile matter diminishes
2. The percentage of fixed carbon increases
3. The thickness of the fire increases
4. The percentage of ash increases
5. The volume of the interstices diminish.

The dust and moisture content of the fuel affect the fuel bed resistance to a considerable extent. Fuel beds which show a screen test of approximately 50 per cent of dust will have about twice the resistance, and consequently can be burned at only about one-half the combustion rate, of those containing only 5 to 10 per cent. The draft loss through the fuel bed is materially reduced when the fuel contains sufficient moisture to agglomorate the dust and the combustion rate with a given draft intensity is considerably increased. This improved combustion is due to a mechanical and not, as is often supposed, to a chemical action.

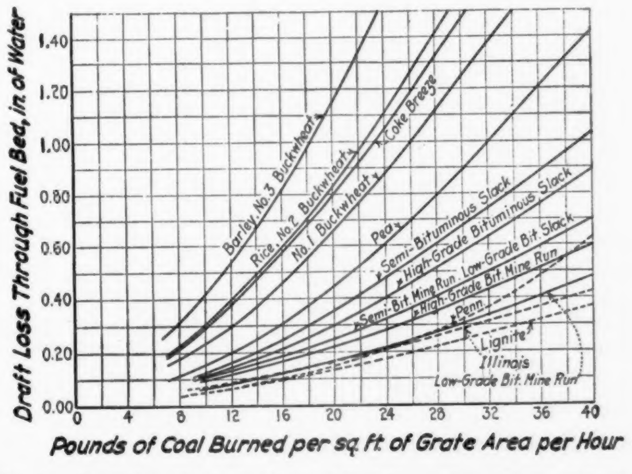

Fig. 1—Draft loss through the fuel bed for various kinds of fuels.

The draft loss varies as the percentage of solids (fixed carbon and ash) in the fuel since the character of the fuel bed is determined by the solid matter and not the volatile. Hence a greater combustion rate can be maintained with a high volatile coal than with one with a low volatile content with the same draft intensity.

Insufficient draft will cause the fuel to accumulate on the grates with the result that the fire will become dead and smoky and the combustion consequently poor. If there is an excess of draft, the fuel will be rapidly consumed on parts of the grate, leaving the fire thin in spots and resulting in losses due to an excess of air. It is therefore of great importance that the draft be regulated properly for every kind of coal. Good firing practice requires a vacuum of approximately 0.10 in. of water in the furnace chamber of forced draft installations. A slight plenum over the fire will result in a higher boiler efficiency but the furnace walls and other parts of the setting will deteriorate rapidly and also gases will escape through inspection ports and leaks into the boiler room. A slight vacuum over the fire not only prevents the gases from escaping but also induces a flow of air through the furnace walls and leaks and, as a result, the walls are kept cooler.

Specific requirements for the amount of draft required to burn the various kinds and grades of coal at various rates of combustion in stoker-fired installations should always be obtained from the stoker manufacturer.

A thorough analysis should be made of the coal that will be burned so that the proper assumptions may be made as to the amount of draft required to overcome the resistance between the ashpit and the furnace chamber. Under ordinary operating conditions, approximately 0.10 in. of water is equivalent to about eight feet of a natural-draft chimney. A difference of one or two tenths in. of water in the assumption of the draft loss through the fuel bed will result in the loss of several feet of chimney that is required if the assumed loss is underestimated. Many of the operating troubles encountered in ordinary plants may be traced to the fact that wrong assumptions have been made as to the draft loss through the fuel bed, resulting in a chimney that is much too short. In forced and induced draft systems, however, such wrong assumptions do not lead to as serious consequences since it is much easier and less costly to provide ample reserve for available draft in blowers and exhausters than in natural-draft chimneys.

In making the preliminary assumptions for the draft loss through the fuel bed, due allowances should be made for a possible change in the grade of fuel to be burned and also in the rate of combustion. For example: assume that the coal to be burned at first is a low-grade bituminous mine-run and that the rate of combustion will be 25 lb. per sq. ft. of grate surface

per hr. In this case the draft loss will be 0.25 in. of water as given by Fig. 1. Later on, if the coal is changed to a high grade semi-bituminous slack, the draft loss will be 0.35 in. of water at the same rate of combustion, an increase of 40 per cent. On the other hand, assuming a semi-bituminous mine-run coal with a combustion rate of 20 lb., the draft loss will be 0.27 in. of water but when the combustion rate is increased to 35 lb., the draft loss will be 0.55 in. of water, an increase of about 57 per cent. Therefore, when making a selection of any type of draft system, a value for the draft loss through the fuel bed should be selected which will suffice not only for the highest rate of combustion which will be encountered but also for the grade of coal which has the greatest resistance through the fuel bed and which may be burned at a later date.

It is by far the better practice to have an excess of draft rather than an insufficiency, provided it is possible to properly and conveniently control its available intensity. An insufficient draft intensity as created by any type of draft system is invariably reflected in the burning of the fuel and in the ultimate boiler efficiency. If there is an excess of draft due to ample reserve of the pressure transformer, it may be controlled by means of a damper in a natural-draft system, or by varying the speed of the driving unit in the case of mechanical draft systems. But if there is no reserve and the available intensity is insufficient for the maximum requirements, the entire plant is under a severe handicap.

In pulverized-fuel and oil-fired installations, there will be no draft loss through the fuel bed since there is none and, consequently, this factor becomes zero in the general draft equation. All other factors being constant, the height of the chimney in natural-draft systems burning pulverized fuel or oil will be less than the height in hand- or stoker-fired installations, and the driving unit in mechanical draft systems will be of less power since the head against which the fan operates is not as great in the former as in the latter case.

Draft Loss Through the Boiler and Setting

The draft loss through the boiler and setting (h_B) also varies between wide limits and, in general, depends upon the following: type, size and design of the boiler, arrangement of tubes and heating surfaces, arrangement of baffles, design and arrangement of brickwork setting, type of grate, location of uptake, and rate of operation and excess air admitted which involve the class and quantity of fuel used and the combustion conditions under which it is burned.

Curves showing the draft loss through the boiler and setting are usually based on the load as expressed in terms of percentage of normal rating. Owing to the great variety of boilers of different designs and the various schemes of baffling, arrangement of tubes, and methods of brickwork setting, and also the great number of factors which affect the quantity of gases generated, it is practically impossible to group together a set of curves of the draft loss through the boiler and setting which may be used generally. The curves of the draft losses for the various boilers should be obtained from the manufacturer of the boiler used. Fig. 2 gives a few curves showing the draft loss through the boiler and setting of several makes of boilers at various ratings. These curves should not be used for general

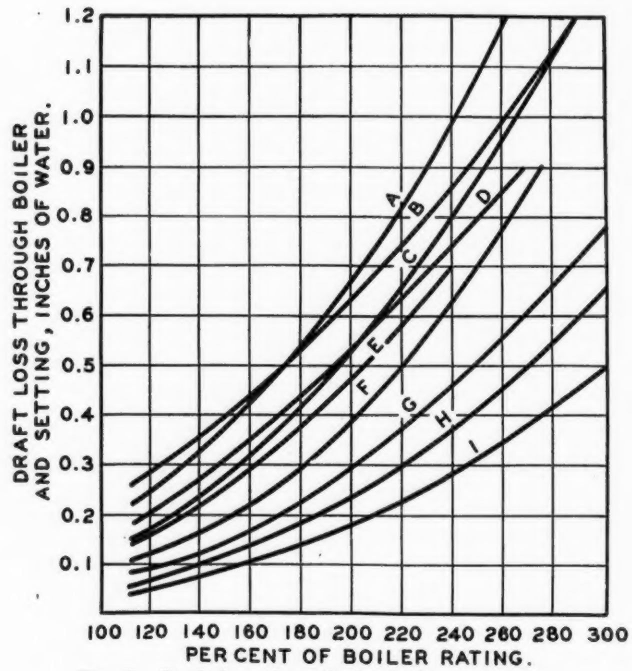

Fig. 2—Draft loss through the boiler and setting.

A—4 pass, vertical baffle, 14 tubes high
B—5 pass, vertical baffle, 16 tubes high
C—4 pass, diagonal baffle, 14 tubes high
D—3 pass, vertical baffle, 16 tubes high
E—3 pass, vertical baffle, 14 tubes high
F—3 pass, vertical baffle, 12 tubes high
G—3 pass, diagonal baffle, 14 tubes high
H—3 pass, diagonal baffle, 16 tubes high
I—3 pass, diagonal baffle, 18 tubes high

purposes. A variation in any one of the several factors noted in the previous paragraph while the others remain constant causes an appreciable variation in the draft loss. These factors are capable of so many variations that no general set of curves can be shown which will be sufficiently comprehensive for general practice. Each combination of boiler, fuel and combustion conditions must be considered and analyzed independently.

It is extremely important that accurate and reliable information be obtained on the draft loss through the boiler and setting. After the type of boiler to be used and also the maximum rating at which it is to be operated have been decided upon, a value for this loss should be selected which will represent the maximum loss when the boiler is operated at its maximum, and not normal, rating. This factor is of vital importance since many errors have been made by assuming the draft loss at a figure which represents the loss when the boiler is operated only at its normal rating.

The draft loss varies directly as the size of the boiler and the length of the gas passages within. The loss also varies as the number of tubes high but not in direct ratio inasmuch as the loss due to the reversal of flow at the ends of the baffles remains constant regardless of the height of the boiler. The arrangement of the tubes, whether the gases flow parallel to, or at right angles to, the tubes has an appreciable effect on the loss. The arrangement of the baffles influences the draft loss greatly, the loss through a boiler with five passes, for example, being greater than that through one with four passes. A poor design and a rough condition of the brickwork setting will increase the loss while a proper design and a smooth condition of the brickwork will decrease the loss and keep it at a minimum. The loss will be less when the breeching entrance is located

at or near the top of the boiler than when it is located at or near the bottom since the gases have a shorter distance to travel in the former case.

If the mean temperature of the gases and the amount of excess air remains constant, the draft loss varies as the square of the amount of gases generated and flowing which is a more convenient method of expressing the load. With natural-draft systems, the proportion of excess air increases with increased vacuum in the setting and consequently a greater weight of gases are dealt with per horsepower at the higher loads and the draft loss increases at a greater power than the square of the load, approximately as the 2.2 to 2.5 power. With forced draft systems, however, the reverse is true since less excess air is required with the higher loads and the loss increases at a lower power than the square. Theoretically the excess air should not affect the draft loss but practically it does affect it materially. The mean temperature of the gases increases with the load since the furnace temperatures are higher.

Small loads can be carried with forced draft systems without the aid of a chimney due to the static draft or "chimney effect" of the boiler and setting. The limit of the load carried occurs when the draft loss is approximately equal to the static draft in the setting. The static draft in the setting is due to the difference in weight of gases within the setting and that of a column of external air equivalent in height to that of the setting. In determining the intensity of the "chimney effect," three temperature regions are considered: from the grate level to the bottom row of tubes where the gas temperature ranges between 2500 and 3000 deg. fahr.; through the tube bank where the gas temperature ranges between 1000 and 1500 deg. fahr.; and from the top row of tubes to the uptake where the gas temperature ranges between 400 and 700 deg. fahr. The equivalent chimney height will vary from 20 to 80 ft., or more, and the static draft from 0.20 to 0.80 in. of water, or more. The total draft loss through the setting is the difference in reading between the gage at the furnace and the uptake, plus the static draft.

In constructing curves of draft loss against load, the true draft loss is first computed and the "chimney effect" then deducted. This curve of the true draft loss originates at zero. When the chimney effect is deducted the apparent draft loss is a minus quantity at loads around 50 per cent of rating and less. This explains the phenomena of a negative draft at light loads when the vacuum near the fire is greater than that at the damper. The chimney effect of settings is greater with high settings such as a vertical or semi-vertical bent tube boiler than with a low-set horizontal water tube or return tubular boiler. In vertical or semi-vertical bent-tube boilers having high combustion chambers, the vacuum at the bottom of the chamber is higher than at the top.

The draft loss through the boiler varies as the amount of gases flowing through it which, in turn, depends upon the proportion of excess air admitted for combustion. The amount of excess air admitted is measured by the CO_2 content in the gases: the less the amount of CO_2, the greater the amount of excess air and, hence, the greater the draft loss. If the proportion of excess air and the temperature of the gases remains constant, the draft loss will vary as the square of the velocity of the gases, or as the square of the load, so that at 200 per cent of rating, for example, the draft loss will be four times that at 100 per cent, or normal, rating. As the excess air increases with lowered CO_2 content, the weight of gases increases but the draft loss which varies as the square of the velocity also varies as the square of the weight of the gases. An increase in the proportion of excess air increases the temperature of the exit gases and consequently the mean temperature in the setting, reduces the boiler efficiency, increases the weight of gases, and consequently further increases the weight per horsepower.

Any arrangement whereby the draft loss is decreased means a loss in heating efficiency since both the rate of heat transfer and draft loss increase with an increase in gas velocity. A balance must therefore be maintained between the heating efficiency and the cost of draft production. Horizontal water-tube boilers with vertical baffles offer more resistance than horizontal baffles but give higher rates of heat transfer.

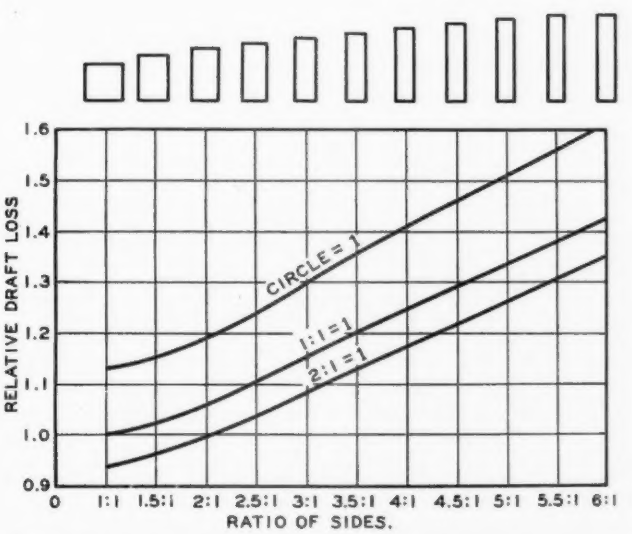

Fig. 3—Relative draft loss for various sections of breeching.

Draft Loss Through the Breeching

The draft loss through the breeching (h_{Br}) is given by the equations:

$$h_{Br} = \frac{0.00414\ B_o\ f\ L\ V^2}{T_c\ C_{br}} \tag{4}$$

$$= \frac{0.00216\ W^2\ T_c\ f\ L}{A^2\ B_o\ C_{br}} \tag{5}$$

in which h_{Br} = draft loss through the breeching, in. of water,
B_o = barometric pressure, in. of mercury
f = friction coefficient
L = length of breeching, ft.
V = gas velocity in breeching, ft. per sec.
T_c = absolute gas temperature in breeching, deg. fahr.
C_{br} = hydraulic radius of breeching section = area of section divided by perimeter of section
W = weight of gases flowing through the breeching, lb. per sec.
A = area of breeching section, sq. ft.

These equations are not theoretically true but give sufficiently accurate results for all practical purposes. It has been the usual custom to assume this loss at 0.10 in.

of water per 100 ft. of breeching length. This practice is hazardous and has no more foundation in fact than that of assuming that the friction loss of water in pipes is equal to an arbitrary figure without taking into consideration the diameter of the pipe and the velocity of flow. For example: assuming a gas velocity of 35 ft. per sec., a friction coefficient of 0.016, a chimney gas temperature of 600 fahr., and a breeching area of 78.5 sq. ft. (equivalent to the area of a 10-ft. dia. chimney) in the shape of a rectangle with the height equal to twice the width; then, for 100 ft. of breeching length, $h_{Br} = 0.11$ in. of water. However, for a breeching area of 28 sq. ft. (equivalent to the area of a 6-ft. dia. chimney) with the same shape and also similar operating conditions, $h_{Br} = 0.184$ in. of water. An assumed value of 0.10 in. of water per 100 ft. of breeching length will generally hold true for the loss through large breechings but for medium and small size breechings the loss will be from 2 to 4 times this figure. In determining the draft loss through the breeching, the gas velocity and the size and shape of the breeching should always be taken into consideration.

Boiler breechings, or flues as they are more commonly called, seem to be subject to the same inconsistencies of design as natural draft chimneys. The usual procedure is to determine the area by a rule-of-thumb method whose existence has no more foundation than that of determining the size of a chimney from a table of chimney sizes based only on boiler horsepowers, and then to construct the duct of a shape that will fit the surroundings. One method is to make the area of the breeching from 20 to 30 per cent greater than the area of the chimney. If the area of the chimney has been incorrectly determined, the error will then be passed on to the size of the breeching. Another commonly used method is to allow a certain number of square feet, usually between 20 and 30, of breeching area per 1000 boiler hp. If the wrong boiler rating has been selected, then the size of the breeching will be too small for the maximum boiler ratings. Breechings should be designed in the same rational manner as chimneys. Their size is determined primarily by the amount of gases which they are to carry away.

It is obvious that the design of a boiler breeching involves its size and also its shape, the length being arbitrarily limited to the distance between the chimney

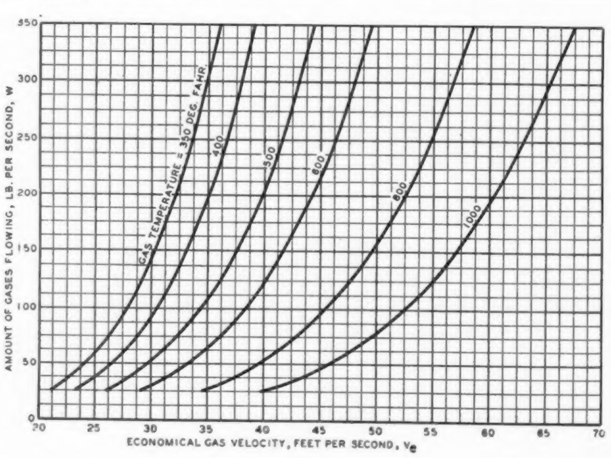

Fig. 4—Economical gas velocities (based on sea level atmospheric conditions, atmospheric temperature of 62 deg. fahr., and friction coefficient of 0.016).

and the boiler farthest from the chimney. The area is determined from an equation which includes all of the factors representing the various operating conditions to which the plant is subjected. Its shape, however, is a matter of economics and also feasibility of construction and deserves attention not only from the standpoint of the breeching itself but also from that of its surroundings, such as the chimney, boiler house, boilers, etc. Head room, the opening into the chimney, the type of boilers used, and many other factors may affect the shape but have no effect on the size.

The equation for the area of the breeching as derived from the equation for a perfect gas is:

$$A_{br} = \frac{0.72\ W\ T_c}{B_o\ V} \qquad (6)$$

in which A_{br} = area of breeching, sq. ft.
W = amount of gases flowing, lb. per sec.
T_c = absolute gas temperature of breeching gases, deg. fahr.
B_o = barometric pressure, in. of mercury
V = breeching gas velocity, ft. per sec.

All of the factors in this equation can be ascertained from the operating conditions of the plant with the exception of the gas velocity. If a high value is assumed for the velocity, the area of the breeching will be relatively small but the friction loss will be high. On the other hand, if a low value is assumed, the area will be relatively large but the friction loss will be low. High friction losses result in larger draft producing systems with the consequent higher first costs while low friction losses result in larger size breechings with resultant higher first costs. The proper and most economical area is that which results from a compromise between a high friction loss and a large size. Therefore, the velocity which will result in a breeching size which will effect a compromise between an excessively high friction loss and an excessively large area, or size, will be the most economical velocity to use.

In determining the most economical chimney size for an operating plant, an equation for the economical chimney gas velocity can be derived which, when substituted in the equation for the height and diameter of the chimney, will result in a chimney size the cost of which will be less than that of any other size as determined by any other velocity. This equation can be used for determining the area of the most economical size of breeching and is:

$$V_e \left[\frac{2.5\ T_c \left(\frac{1}{T_o} - \frac{1.04}{T_c} \right) \sqrt{\frac{W\ T_c}{B_o}}}{f} \right]^{2/5} \qquad (7)$$

in which V_e = economical gas velocity for breeching, ft. per sec.
T_o = absolute atmospheric temperature, deg. fahr.
T_c = absolute gas temperature of breeching gases, deg. fahr.
W = weight of gases flowing through the breeching, lb. per sec.
B_o = barometric pressure, in. of mercury
f = friction coefficient.

When the value of the economical gas velocity as determined from this equation is substituted in equation (6) for the area of the breeching, a size will have been attained which will be a compromise between an ex-

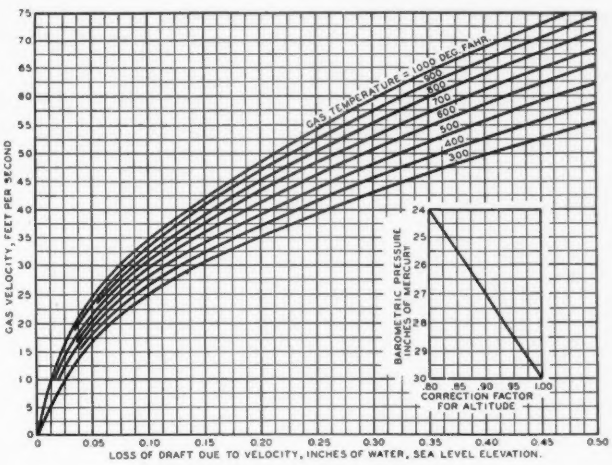

Fig. 5—Draft loss due to velocity.

cessively high friction loss due to a smaller size and an excessively high first cost due to a larger size.

Example: Determine the most economical area of breeching from the following data:

Breeching gas temperature, 500 fahr.,	$T_c = 960$
Atmospheric temperature, 62 fahr.,	$T_o = 522$
Sea level elevation,	$B_o = 30$
Friction coefficient,	$f = 0.016$
Maximum amount of gases flowing,	$W = 172$

Substituting these values in equation (7) and reducing:

$$V_e = (9140)^{2/5} = 38.4 \text{ ft. per sec.}$$

Substituting these values in equation 6 for the area of the breeching, then for an economical gas velocity of 38.4 ft. per sec.:

$$A_{br} = 104 \text{ sq. ft.}$$

For the operating conditions noted, the area of 104 sq. ft. represents the most economical area, above which, the size and cost of the breeching will be excessive, and below which the friction loss will be excessive.

The size and shape of breechings are of great importance in a steam plant since many operating troubles can be traced to improper designs and arrangements of this connection. After the economical area of the breeching has been determined, the shape of the duct should receive careful consideration. A breeching with a circular cross-section results in the least relative draft loss but a circular breeching is ordinarily more costly than one with a square or a rectangular section. Also constructional difficulties are encountered in connecting it with the shaft of chimneys, particularly with those of the smaller sizes. A circular breeching requires considerable space and in most plants available room for breechings is at a premium. Square breechings also require considerable horizontal space and likewise are difficult to connect with the shaft of the chimney.

Most breechings are therefore constructed rectangular in section and with the height equal to twice the width. This shape requires the least horizontal space in the plant and moreover has the added advantage of a direct connection to the shaft of the chimney without inducing complications in regard to the breeching opening.

When an opening is cut into, or placed in, the walls of a masonry chimney, a considerable area of a section through the chimney at this region is left out, and unless something is done to strengthen the shaft around the breeching opening, the structure is considerably weakened as a result. Accordingly, pilasters are built on each side of the breeching opening to compensate for the masonry taken away, the size of the pilasters depending upon the amount of material taken away; but, at any rate, the cross-sectional area of the pilasters should equal the area left out. It is obvious then that the width of the opening should be as narrow as possible, thus accounting for the fact that most breechings are made rectangular in section. The breeching could be developed from a rectangular section at the entrance to the chimney to any other shape desired, but this procedure would incur considerable expense which would not be warranted by the saving in the additional height to the chimney required by the increased friction loss due to a more disadvantageous shape. The above remarks also apply to steel chimneys in a general way but the adverse conditions are not so pronounced.

TABLE I
SIZES OF RECTANGULAR BREECHINGS

Diameter of Chimney		Area of Chimney, or Breeching	Size of rectangular breeching with ratio of sides of 2:1			
			Width		Height	
ft.	in.	sq. ft.	ft.	in.	ft.	in.
3	9	7.1	1	11	3	9
3	6	9.6	2	2	4	5
4	0	12.6	2	6	5	1
4	6	15.9	2	10	5	8
5	0	19.6	3	1	6	5
5	6	23.8	3	5	6	11
6	0	28.3	3	9	7	7
6	6	33.2	4	1	8	2
7	0	38.5	4	5	8	9
7	6	44.2	4	8	9	6
8	0	50.3	5	0	10	1
8	6	56.7	5	4	10	8
9	0	63.6	5	8	11	3
9	6	70.9	5	11	11	11
10	0	78.5	6	3	12	7
10	6	86.6	6	7	13	2
11	0	95.0	6	11	13	8
11	6	103.9	7	2	14	5
12	0	113.1	7	6	15	1
12	6	122.7	7	10	15	8
13	0	132.7	8	2	16	3
13	6	143.1	8	5	17	0
14	0	153.0	8	9	17	7
14	6	165.1	9	1	18	2
15	0	176.7	9	5	18	9
15	6	188.7	9	8	19	6
16	0	201.1	10	0	20	2
16	6	213.8	10	4	20	8
17	0	227.0	10	8	21	4
17	6	240.5	11	0	21	10
18	0	254.5	11	4	22	6
18	6	268.8	11	7	23	3
19	0	283.5	11	10	23	11
19	6	298.6	12	3	24	5
20	0	314.2	12	7	25	0

The relative draft loss through the breeching for various sections is shown graphically by Fig. 3. For the same sectional area, the draft loss is least through a breeching with a circular section and greatest through a breeching with a rectangular section. For rectangular sections, the draft loss increases as the ratio of the sides increases, or as the width of the breeching decreases, all other conditions remaining the same.

While the area of the breeching is determined by the amount of gases passing through it, the result should be checked by comparing it with the minimum area of the chimney. The greatest area of the breeching should be at least as large as, and preferably greater than, the minimum area of the chimney.

Breechings should always be as short as possible. Overhead breechings are more desirable than underground breechings. The bends in the breeching should have as wide a sweep as possible. The corners of the connection on the inside, especially the one on the side of the direction of flow of the gases, should be rounded

out in order to decrease the friction loss and also to prevent eddies.

Table 1 gives the size of rectangular sections of breechings entering the shaft of chimneys of various diameters, based on a ratio of sides of 2:1. The area of the breeching, of course, increases as the number of boilers connected to it increases, the maximum area being over the boiler nearest the chimney and this maximum area being continued from thence to the chimney. Since the breeching must convey the same amount of gases as the chimney, it follows that the area of the breeching at its greatest section must be at least as great as the minimum area of the chimney. When breechings of a circular section are used, the areas are made the same throughout the entire length. In the case of rectangular sections, however, the area is usually increased to a slight extent over that of the theoretical requirements to allow for possible dead air spaces in the corners, particularly in sizes of 50 sq. ft. and less.

Draft Loss Due to Velocity

The draft loss due to velocity (h_V) is the head exerted on a plane perpendicular to the direction of flow, less the pressure head. It represents the portion of the total draft necessary to accelerate the gases and is often called the draft loss due to acceleration. This loss is given by the equations:

$$h_V = \frac{0.00414\ B_o\ V^2}{T_c} \qquad (8)$$

$$= \frac{0.00216\ W^2\ T_c}{A^2\ B_o} \qquad (9)$$

in which h_V = draft loss due to velocity, in. of water
B_o = barometric pressure, in. of mercury
V = gas velocity, ft. per sec.
T_c = absolute gas temperature, deg. fahr.
W = weight of gases flowing, lb. per sec.
A = area duct, sq. ft.

Fig. 5 gives the draft loss due to velocity for various values of velocity and gas temperatures and also correction factors for altitude variations.

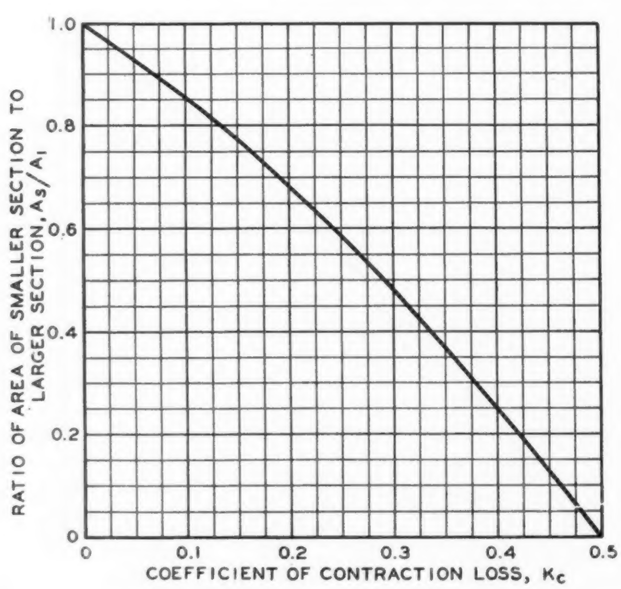

Fig. 6—Coefficient of contraction loss.

Equations (8) and (9) applies to all cases where the change in velocity is from 0 to V, or where the movement of the gases is started from rest. For a change of velocity from V_a to V_b, then equation (8) becomes:

$$h_v = \frac{0.00414\ B_o}{T_c} (V^2_a - V^2_b) \qquad (10)$$

For low velocities and high gas temperatures, the intensity of the velocity head is small and may be neglected. For example: for a gas velocity of 20 ft. per sec. and a gas temperature of 1000 fahr., $h_V = 0.034$ in. of water. However, for average operating conditions, the gas velocity is approximately 35 ft. per sec. and the gas temperature 600 fahr., from whence $h_V = 0.143$ in. of water.

The total draft required to impart a definite velocity to a quantity of gas is the sum of the velocity and contraction heads. Whence, from equations (8) and (9) when $K_c = 0.5$:

$$h_{VC} = \frac{0.00621\ B_o\ V^2}{T_c} \qquad (11)$$

$$= \frac{0.00325\ W^2\ T_c}{A^2\ B_o} \qquad (12)$$

in which h_{VC} = draft required to impart velocity to a gas stream
B_o = barometric pressure, in. of mercury
V = gas velocity, ft. per sec.
T_c = absolute gas temperature, deg. fahr.
W = weight of gases flowing, lb. per sec.
A = area duct, sq. ft.

For average operating conditions, the total draft required to impart velocity to a quantity of gas when the gases, with a temperature of 600 fahr., start from rest and increase in velocity to 35 ft. per sec. is 0.215 in. of water.

Draft Loss Due to Abrupt Enlargement

When the duct through which the gases flow is abruptly enlarged, or suddenly expanded, so that the speed of the gases is altered, a portion of the velocity head is converted into static head in the larger section. The difference between the total velocity head and the amount converted into static head is the head, or draft, loss due to abrupt enlargement. This loss is expressed by the equations:

$$h_E = \frac{0.00414\ B_o}{T_c} (V_1 - V_s)^2 \qquad (13)$$

$$= \frac{0.00216\ W^2\ T_c}{B_o\ (A_1 - A_s)^2} \qquad (14)$$

in which h_E = draft loss due to abrupt enlargement, in. of water
B_o = barometric pressure, in. of mercury
V_1 = gas velocity in larger section, ft. per sec.
V_s = gas velocity in smaller section, ft. per sec.
T_c = absolute gas temperature, deg. fahr.
W = weight of gases flowing, lb. per sec.
A_1 = area of larger section, sq. ft.
A_s = area of smaller section, sq. ft.

Losses due to abrupt enlargement are ordinarily not

encountered in the average steam plant. In the case of natural draft systems, however, there is usually an appreciable enlargement loss where the breeching enters the shaft of the chimney. This is due to the fact that the internal area of the chimney at the breeching entrance is considerably larger than the area of the breeching; the increased area being due to the hollow truncated cone form of the shaft.

Draft Loss Due to Contraction

When the duct through which the gases flow is suddenly contracted, a considerable portion of the static head in the larger section is lost during the conversion into velocity head. This loss is given by the equations:

$$h_C = \frac{0.00414\ B_o}{T_e} K_c\ V^2_s \qquad (15)$$

$$= \frac{0.00216\ W^2\ T_e}{K_c\ A^2_s\ B_o} \qquad (16)$$

in which h_C = draft loss due to contraction, in. of water
B_o = barometric pressure, in. of mercury
K_c = coefficient of contraction
V_s = gas velocity in smaller section, ft. per sec.
T_e = absolute gas temperature, deg. fahr.
W = weight of gases flowing, lb. per sec.
A_s = area of smaller section, sq. ft.

The value of K_c is a function of the ratio of the areas of the two sections and its values are given by Fig. 6.

For small changes in section, the intensity of the draft loss due to abrupt enlargement and sudden contraction is small and may be neglected but when the difference in area between the two sections is large their intensity is relatively great and particularly so when the draft loss due to friction is small.

The most important draft loss due to contraction occurs when a gas stream enters a duct. In this case, the value of $A_s/A_1 = 0$ and $K_c = 0.5$. If for example the gas velocity in the duct is 35 ft. per sec., then for sea level elevation and a gas temperature of 600 fahr., $h_C = 0.77$ in. of water.

Draft Loss Due to Bends

The draft loss due to a 90 deg. bend is equivalent to the loss due to velocity head for a 90 deg. bend. In changing the direction of flow, the gas velocity at the bend decreases to zero with a loss of velocity head and then increases to its proper value at the expense of a loss in pressure head, the net result being a loss in pressure head equal to the velocity head at the bend. This loss may be calculated from the equations:

$$h_{Bd} = \frac{0.00414\ B_o\ V^2}{T_e} \qquad (17)$$

$$= \frac{0.00216\ W^2\ T_e}{A^2\ B_o} \qquad (18)$$

in which h_{Bd} = draft loss due to bends, in. of water
B_o = barometric pressure, in. of mercury
V = gas velocity, ft. per sec.
T_e = absolute gas temperature, deg. fahr.
W = weight of gases, lb. per sec.
A = area duct, sq. ft.

The draft loss at a right angle bend is sometimes expressed as the equivalent of a straight length of duct of a certain length for a certain diameter, similar to the procedure used in estimating the loss due to bends in piping systems conducting water. Most breechings, however, are built square, or rectangular, in section and a general equation based on the shape of the breeching cannot be conveniently expressed.

Draft Loss Through the Economizer

Draft losses through economizers of present-day design, especially those having extended heating surfaces in the form of fins or gills, vary within such wide limits that no general formulas permit of reasonably accurate results. It is, therefore, advisable to obtain information on losses through economizers from the manufacturers.

Institute of Metals Elects New Officers

At the recent 25th Annual General Meeting of the Institute of Metals, held in London, the following officers were elected for the year 1933-34.

President, Sir Henry Fowler; *vice-presidents,* C. H. Desch and Professor R. S. Hutton; *members of council:* Engineer Vice-Admiral Sir Robert Dixon, Wesley Lambert, H. C. Lancaster, A. H. Mundey, A. J. G. Smout, and F. Tomlinson.

The silver jubilee meeting of the Institute will be held in Birmingham from September 18 to 21. It was in Birmingham that the first general meeting of the Institute was held in the autumn of 1908, under the presidency of the late Sir William H. White.

The Edward Valve & Manufacturing Co., East Chicago, Indiana, is now represented in the District of Columbia by the Dunbar Engineering Co., 601 13th Street, N.W., Washington, D. C. The office is in charge of Mr. P. N. Israel of the Washington Engineering Co. at that address.

The Coppus Engineering Corporation, Worcester, Mass., announces the appointment of Cooper Pogue, Chamber of Commerce Building, Cincinnati, Ohio, as sales representative in the Cincinnati district for its line of Coppus-Annis Dry Type Air Filters for ventilating and industrial purposes.

The National Aluminate Corporation, Chicago, manufacturers of Nalco—K.W.S. sodium aluminate, has awarded a contract to Strobel and Hall for an addition to its factory in Clearing, Ill. This addition will increase the floor space by 40%.

Construction will begin immediately and is to be finished June 1. Ashby, Ashby and Schulze are the architects.

Patents *

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PART X

This article deals with interference procedure which the author says is probably the most complicated branch of American jurisprudence. The circumstance out of which interference proceedings arise and the manner of their institution, whether by the Patent Office or a contestant, are fully discussed. The perogatives of the Patent Office in recognizing interference claims and its method of determining prior rights are explained. The nature and scope of the preliminary statements requested of the contestants are described and the relative importance of the essential parts of such statements are analyzed.

Interference Procedure

MANY and various kinds of litigation arise in connection with patent rights. In most cases, the litigation must be begun by the party who feels his rights are being invaded or evaded. One type of litigation involving patent rights is started by the Patent Office without any request or any initiatory act by the interested parties. This type of litigation is known as an "interference" proceeding. Interference proceedings are probably the most complicated branch of American Jurisprudence and in the following paragraphs, we will analyze some of the simpler phases of this type of patent litigation. One who becomes engulfed in the maelstrom of this type of litigation, in a hard fought interference, has been likened to Sinbad, the sailor. He is drawn into uncharted legal waters, storm tossed by motions, petitions, appeals, and decisions and may enter the doldrums and morass of the Saragossa Sea of legal tangles from which it will take his application years of time to emerge through the interwoven mass of volumes of testimony and decisions, both in the Patent Office and in the Courts.

Interferences Started by the Patent Office

The patent laws require the Patent Office to issue patents to the first and original inventor of a new and patentable invention. It is not unusual for two or more inventors to conceive the same patentable invention about the same time. This has happened with surprising frequency as to new inventions that have been milestones on the pathway of progress. The telephone, electric light, phonograph, moving pictures, radio, talking pictures and other great inventions were worked out substantially contemporaneously by independent inventors. This has occurred so often that it almost leads one to conclude there is some foundation for mental telepathy, or that there is a common source from which we draw our creative thoughts. However, the Patent Office does not concern itself with metaphysics. It is interested only to find out who is the first inventor.

Where a plurality of such inventors have filed copending applications for patents upon the same invention, the fat is in the fire and the trouble begins. Usually, each inventor discloses a different concept of a common broad invention and in one way or another attempts to cover this common invention by claims. The Patent Office cannot grant two valid patents on this same broad invention, so, therefore, the Patent Office starts a proceeding whereby each such inventor may submit evidence to prove his date of inventorship so that the Patent Office may decide which inventor is entitled, under the law, to the patent for the common subject-matter. The starting of such a proceeding by the Patent Office is known as declaring "an interference."

An Examiner in examining cases develops a retentive memory as to structure and subject-matter of cases he is examining, and if he takes up a case which seems familiar subject-matter, he will look back through his pending files to see if some pending application does not disclose and claim the same invention. Also, whenever an application is allowed, the Examiner makes a final search by looking through all pending applications of the same general subject-matter as the case which he is about to allow. If the case is entirely free from conflict with other pending applications, it is passed to allowance. If, however, the Examiner finds that some pending application conflicts with the case he is about to allow, then a situation arises where an interference proceeding may be started.

An applicant for patent is supposed to claim all of the novel subject-matter disclosed in his application upon which he desires a patent. Novel subject-matter which he does not claim is dedicated to the public when the patent issues. Of course, he is not entitled to a claim covering subject-matter which is not new. Therefore, the rules of the Patent Office provide that interferences will be declared between applications of different parties for patent or for reissue when such applications contain

claims for substantially the same invention which are allowable in the application of each party. Where an application shows a common novel subject-matter shown in some other pending case, but either or neither of the applicants attempts in some way to claim the same, no interference should be started by the Patent Office. However, the Patent Office does not adhere strictly to this rule. Since applications for patents are retained in secrecy by the Patent Office, it is very unlikely for two or more applicants to use identically the same language in making claims to common novel subject-matter and there is probably some claim in each case which shoots generally in the direction of the common ground of invention. The Patent Office gives this probability the benefit of the doubt and usually declares the interference.

All the Patent Office knows about the rights of the parties, so far as dates of invention are concerned, is the filing date of their respective applications in the Patent Office. So far as the Patent Office knows, the applicant who filed first is the first inventor but this may not be the true fact. Therefore, each party is given an opportunity to prove when he made his invention.

Interferences Started by a Contestant

Usually, interferences are initiated by the Patent Office. Occasionally, an interference will be started by one of the contestants. Where an applicant has an application pending, and during the pendency of this application, a patent inadvertently issues with claims directed to the invention the applicant is claiming, the applicant may copy the claims from the patent and request an interference to be declared. Of course, under these conditions, the patent should not have issued but the Patent Office is not infallible and errors are bound to occur.

It sometimes happens that a patent will issue on an invention which is being worked up by some other inventor who has not filed his application. This inventor may read through the Official Gazette each week, and find an extract from some patent directed to the same invention he is perfecting. He may immediately prepare and file an application and copy claims from the previously granted patent and request an interference.

It also happens occasionally that a patent will be granted and within a short time after the grant of the patent, another patent will issue with claims which the first patentee feels cover an invention that belonged to him. The first patentee may reissue his patent and copy the claims of the other patent in his reissue and request an interference.

Ordinarily, where claims are copied from a patent for the purpose of an interference, such claims must be made within two years from the issue of the patent, regardless of whether the party copying the claims filed his application before or after the patent issued. There may be exceptional circumstances where this rule of law does not apply but this is the general rule. This practice is not governed by any specific statute but grows out of the Court's interpretation of the law. In our discussion of reissues, we pointed out that a reissue with broadened claims would not ordinarily be allowed if it was filed two years after the original patent issued due to the presumption that intervening rights had arisen. The rule of law we are at present discussing also presumes intervening rights would arise within two years after the patent issued, which would make it inequitable for one who waited more than two years to copy the claims of an issued patent and ask for an interference. The tendency of the Courts is to facilitate carrying out the fundamental principles of the patent laws for the benefit of the public, and the fundamental principle involved is that in order to promote the progress of science and the useful arts, inventors are granted certain exclusive rights for the period of seventeen years, at the end of which time the invention is open for use by the general public. Where a rival inventor copies claims from a patent and starts an interference proceeding, if he wins out, he will take the claims away from the original patentee, which claims will appear in a later patent to the second inventor. The practical effect of this proceeding is to deprive the public of the use of the invention for more than seventeen years. Theoretically, this is not the case because theoretically, the claims were invalid to the first patentee, and, therefore, theoretically, the public had the right to practice the invention until the patent was granted to the really first and original inventor. Therefore, theoretically, the public is deprived of the use of the invention only for seventeen years. Practically, however, it is unlikely for the public to take a chance on manufacturing the patented invention after the first patent issues and consequently the public is deprived of the use of the invention from the grant of the first patent to the expiration of the second patent. Therefore, if there is to be a second patent, the party demanding the same should not be allowed to sleep on his rights, hence the rule compelling him to act within the two year limit.

An interference requires at least two applicants, but is by no means limited in the number of applicants which may be involved. Of course, each of these applicants must be claiming at the same invention. Some years ago, a certain invention was demonstrated at a convention of an association. The various members of the association went back home and many of the members worked out their own individual ideas of a device for carrying out the stunt which they had seen at the convention. Many of them filed applications for patents. The result was that ninety some applications for patents came into the Patent Office within a short time of each other, each of which disclosed a common invention, and most of which had claims to this common invention. It was a simple invention and the Commissioner of Patents took the position that the solution of the problem was so simple and it had been solved by so many different people in different parts of the country that it was really not a patentable invention, but was in fact a specific application of "skill of the art." Skill of the art is not patentable, and is merely the using of the knowledge of yesterday to do the job of today whereas invention must go beyond the knowledge of yesterday. The Commissioner, therefore, refused to declare interferences and rejected the claims on the broad common subject-matter, but did allow specific patents on specific devices which the several applicants had invented. This was an unusual situation.

It occasionally happens that two or more parties whose claims are in conflict will be represented by the same attorney. This is not unusual where there are several members of a firm or assistants, each working more or less independently, but wherein the work is all

actually under a general firm name. Where this situation arises, the Patent Office will notify each applicant and also the attorney of this fact. Attorneys usually attempt to avoid this situation, but sometimes where it arises accidentally it may be advantageous to the parties having the conflict to have a common attorney because they may be able to negotiate their difficulties more easily than if the matters were in separate law offices where the attorneys might be impelled to encourage the contestants to fight.

Where no settlement is likely to be consummated usually one or the other or sometimes both clients will seek other counsel. There have been thoroughy contested interferences where different members of the same firm have represented the contesting parties, of course, with full knowledge of all parties concerned. Interferences are like other legal matters determined by mixed questions of fact and law, and a contestant who has become well acquainted with his individual attorney, may have great faith in the ability of his attorney and may be perfectly willing to entrust his case to this individual even though he may be in the same organization as his opponent's counsel.

Request For Date Of Invention

It not infrequently happens that an application has been pending in the Patent Office for some time and another applicant files an application which interferes with the subject-matter claimed in the early application. Under these conditions, it often happens that the second inventor did not complete his inventive concept until some date after the filing date of the earlier case. Under these conditions, the first applicant would obviously win the interference and the Patent Office would require no proof beyond the filing dates of the respective applications. If the facts were known by the Patent Office the declaring of such an interference would be merely a useless gesture. To avoid the necessity of declaring such useless interferences, the Patent Office, under the above conditions, usually writes a letter to the second applicant requiring him to state in writing the date when he conceived (that is when he first got the completed invention worked out in his mind,) the invention defined by certain specified claims in his application. If the date of conception of the invention given by the second applicant is subsequent to the filing date of the early applicant, no interference will be declared. The first applicant will be permitted to obtain a patent on the common subject-matter and then the second application will be rejected on this patent. Where the date of conception of the second applicant antedates the filing date of the early applicant, an interference between these applications will usually be declared. This letter from the second applicant is not recognized as an official communication and is returned to the second applicant after the Patent Office has considered it. All official communications must be retained in the application file, so that this type of letter is considered unofficial and is an exception to the general rule.

Suggestion Of Claims

In the olden days, the applications were placed in interference on claims of different wording and phraseology. This led to great confusion because the party who felt he could win the interference would insist that the interference was properly started and should continue. The party who felt that he was about to lose the interference would insist that his claim meant an entirely different thing from the claim of the other applicant and that the interference should never have been declared and should be terminated to permit each party to obtain a patent on his specific invention. To obviate this difficulty, the Patent Office now suggests conflicting claims from one party to the other before the interference is started. In other words, if the Examiner decides that two inventors are claiming at the same invention, he will pick out one or more claims from one applicant and will write an official letter to the other applicant suggesting that if the other applicant wishes to contest an interference on these claims, he must make the claims in his case by way of amendment within a definite period, usually twenty days, or else he will be held by the Patent Office to have disclaimed the subject-matter covered by the suggested claims. Copies of the letter suggesting claims will be sent to the attorney, the applicant, and the assignee where there is an assignment of record in the Patent Office. Sometimes the suggested claims are all taken from one application and suggested to another applicant. At other times, they may be taken from the different applications and suggested to opposing parties by cross correspondence. Now, if the party to whom the claim is suggested, copies the claim by way of amendment in his case within the time allowed, then the interference is officially "declared."

Applicants sometimes feel an injustice has been done them by the Patent Office in suggesting their claims to a rival inventor. This is especially true where the claims have been allowed only after a hard contest with the Examiner, or by an appeal to the Board of Appeals. Where it is discovered that a conflict of inventions claimed exists, and the date of invention of the last to file antedates the earlier case, the Patent Office should declare an interference. Now if this must be done, it should include the broadest as well as the more specific aspect of the common invention, so that the Examiner selects the broadest allowed claims in either of the conflicting applications as one boundary of the field of battle between the contestants. It does seem a bit hard to suggest a finely worded broad claim to some applicant who has been making more or less indifferent types of claims, but there seems no way to avoid this procedure.

Where one assignee of record in the Patent Office owns more than one application in conflict with other parties, the Patent Office will require the assignee to elect one application on which to contest the interference.

Declaration of Interference

The law provides that:

> "Whenever an application is made for a patent which, in the opinion of the Commissioner, would interfere with any pending application, or with any unexpired patent, he shall give notice thereof to the applicants, or applicant and patentee, as the case may be, and shall direct the primary examiner to proceed to determine the question of priority of invention."

The joker in the above quoted statute is in the words "in the opinion of the Commissioner." This means that

the declaration of interference is entirely within the discretion of the Commissioner and we have observed that where an official act is purely discretionary, the Courts will not compel the official to act nor is there any appeal from the official's action or refusal to act. It is under the wording of this statute that the Patent Office finds authority for its procedure in writing letters to applicants requesting their date of invention, as has been previously pointed out. As a matter of truth and fact, under those conditions, an interference really exists, but if the first applicant files so many years ahead of the second applicant that the second applicant has no chance to win the interference, then the Patent Office declines to start any interference, because whether or not an interference exists is left by the law entirely to "the opinion of the Commissioner."

When this practice was started by the Patent Office a few years ago, a party who had filed last felt he had a right to have the interference declared even though he might not win out, and upon refusal of the Commissioner to declare the interference, he went to the Court in an attempt to mandamus the Commissioner of Patents to compel him to declare the interference. The case was carried through to the Supreme Court of the United States. The Supreme Court decided that where the party last to file did not conceive the invention until subsequent to the filing date of the first applicant, that the Commissioner was entirely within his rights in refusing to declare the interference since the action taken was controlled by "the opinion of the Commissioner."

It, therefore, appears, that the declaration of the interference is more or less within the discretion of the Commissioner. The practice of the Patent Office, however, is uniform that an interference will be declared between applications claiming at common subject-matter and wherein the applications are filed within a few months of each other or wherein the latest applicant states his conception of the invention ante-dates the filing date of the earliest applicant.

The rules of the Patent Office require that the claims which are to be put in interference must be patentable claims so far as the Patent Office knows and that preliminary questions as to the allowance of the applications shall be settled before the interference is declared. The Patent Office, however, usually declares an interference when one application is in condition for allowance without waiting for the other applicants to place their cases in condition for allowance.

After the preliminaries have been passed, the Primary Examiner in charge of the conflicting cases forwards to the Examiner of Interferences a tabulated statement identifying the applications in interference in inverse chronological order of filing of the completed applications. He also picks out the claims common to both applications which shall constitute the issue of the interference.

The jurisdiction of the conflicting applications has now passed from the Primary Examiner to the Examiner of Interferences and no further action in the case can be taken before the Primary Examiner without jurisdiction of the application being restored to him by order of the Commissioner.

The Patent Office now sends out to each of the contesting parties and their assignees the "Declaration" of the interference. This declaration comprises a copy of each claim which is to be an issue in the interference. Following these claims, which are now numbered in series and are called "counts" of the interference, is a schedule identifying each count with a definitely numbered claim of each application. Following this schedule is the name of each applicant, his post-office address, the title of his application, the name and address of the attorney and the name and address of the assignee, if there is an assignment of record in the Patent Office. This "Declaration" of Interferences sets forth a date, usually thirty days in advance, on or before which each party is required to file a preliminary statement.

Preliminary Statement of Domestic Inventors

In the early days of Patent Office procedure, parties who got into interference proceeded to establish their rights by more or less hammer and tong methods and the fights were usually bitter and not always entirely scrupulous. The inventor who files his application last has the burden of proof on his shoulders and he must establish his proofs of invention at least back of the filing date of the inventor who filed first. In these bygone days, there evidently was considerable shifting of evidential material and in some cases perhaps there was downright perjury. The party having the burden of proof was compelled to disclose his main case in its entirety before his opponent began to take any testimony. Therefore, his opponent knew exactly what dates he had to overcome and if he was inclined to be unscrupulous, he knew exactly how far it was necessary for him to go.

To obviate any such temptation on the part of the contestants, the Patent Office practice was long ago amended to require the filing of a "preliminary statement."

When the contestants receive the declaration of interference and thereby know the scope of the invention which is to be contested, they are notified that they must file preliminary statements under oath, before they can get any further information as to their opponent's case. This preliminary statement must set forth under oath the following facts; (a) the date of the original conception of the invention as defined by the claims comprising the counts of the declaration of the interference; (b) the date upon which the first drawing or sketch of the invention was made and the date upon which the first written description of the invention was made; (c) the date upon which the invention was first disclosed to others; (d) the date of the reduction to practice of the invention; (e) a statement showing the extent of use of the invention; and (f) if any foreign patent had been filed before the United States case was filed. If no drawing has been made or if there is no written description or if the invention has not been reduced to practice or disclosed to others, the preliminary statement must set forth the facts.

Preliminary Statements of Foreign Inventors

The above outline for a preliminary statement applies where the invention was originally made in the United States. Where the invention was made abroad, the preliminary statement is slightly different. In that case, the applicant shall swear to the following facts: (1) that the applicant is the inventor of the subject-matter set forth in the counts of the interference; (2) whether

or not the invention was ever patented and if so, give the date and number of the patent, the country and all information relating thereto; (3) whether or not the invention was ever described in a printed publication and if so identify the publication as to title, place, date, etc.; and (4) when the invention was introduced into this country, giving the circumstances with the dates connected therewith which shall be relied upon to establish the fact.

Preliminary statements must be very carefully prepared because these preliminary statements are intended for the purpose of avoiding false testimony. Therefore, if as the interference proceeds, and testimony is offered to set up earlier dates than those specified in the preliminary statements, such proofs will be held to establish only the dates alleged in the preliminary statement and none other. Furthermore, if there is a wide spread between the dates alleged in the preliminary statement and those established on proof, such a circumstance tends to weaken the case of the inventor who swore to the false preliminary statement. In other words, if he swears to one thing in the preliminary statement and when it comes to testimony, he swears to a different thing, the conflict is, of course, not helpful to his case.

In view of the extreme importance which preliminary statements have in their bearing on interference procedure, we will proceed to analyze each of the several requirements of the preliminary statements.

Analysis of Preliminary Statements

The first requirement, namely, the date of original "conception," means the date on which the idea first was completely worked out in the mind of the inventor. This date usually is connected with the date of disclosure, because often an idea occurs to an inventor in conversation with someone who is discussing with him a general mechanical problem. Sometimes, the inventor works out the idea by himself and in doing so frequently makes sketches. These sketches should be dated, as we have hereinbefore pointed out, and such a date made at the time when the sketch is produced will be very helpful, because it fixes the date of conception.

The date of the "first drawing" or sketch, means not working drawings, but any sketch even though it is so crude as to require substantial explanation to show that it was a sketch relating to the invention in issue of the interference. Such sketch will come under the requirements for the date of the first drawing. First "written description" does not necessarily mean a full story of the invention, but may comprise written notations on the sketch which further explain the construction or operation of the device shown by the sketch. If the invention should happen to be a process, then any writing of formulae or other written material may be considered as the first written description.

The date when the invention was "first disclosed to others" is a very important date because it is the foundation of the first step in the proofs which can be corroborated. This means the date when the invention was discussed sufficiently with others so that these other parties may testify as to the fact the invention was explained to them.

The date of "reduction to practice" is an extremely important date because the case may turn largely upon this date. Reduction to practice means the first time the invention was tried out in an operative device. This device may be a crude model, but if it embodies sufficient working parts so that the actual utility of the machine may be tested, such crude device is sufficient. If the invention relates to a steamship or a steam shovel or some such construction of that type, a mere crude model may not be sufficient to establish the practical operation of the invention. On the other hand, under some circumstances, a crude model may be sufficient even in the case where the machine, in actual practice, is a large piece of mechanism. Reduction to practice means the actual making and testing of a machine or device. If a device is constructed but never tested, the reduction to practice will be incomplete. It is not necessary that the reduction to practice shall be embodied in a commercial machine, neither is it necessary that the machine shall be operated to produce articles for sale. All that is necessary is that the machine shall be of sufficient completeness to clearly demonstrate the practicability of the invention. A device which does not work successfully to demonstrate the utility of the invention is not a "reduction to practice" but is merely an experiment. The completed invention has not been demonstrated and further work must be done.

There is a fiction in the law that the filing of an application for patent constitutes a reduction to practice. This is known as a "constructive reduction to practice." This fiction grew up in the law many years ago on the theory that an operative machine disclosed in an application for patent constituted evidence before the Patent Office of the completion of the invention, which is the goal post of the development of an idea. Therefore, a completed application was accepted as fixing this important step. In the case where an invention is simple in character, it often is advisable to actually reduce the invention to practice by making and testing one of the devices before filing the application. Where the device is of such character that the inventor is not able actually to build the device, then, it is advisable to carefully work out the details of the mechanism so as to be sure that the construction is operative and then promptly file an application for patent. The patent laws are intended to reward the diligent and not the slothful. Therefore, the inventor who reduces to practice first either by building the device or by filing an application has a very substantial advantage in an interference contest.

The statement as to the "extent of use" of the invention ordinarily means the extent of commercial use and is not as important as are other requirements in the preliminary statement. It merely tends to strengthen the position that the device is practical and useful.

The "date of any foreign patent" filed before the United States case is important, because if this date is within one year prior to the filing in the United States and the foreign patent application was filed by a citizen or subject of a country which is a member of the Geneva Convention, then the applicant gets the benefit of the filing date in the foreign country as his date of constructive reduction to practice in the United States. This is due to the fact that the Geneva Convention, which is a treaty between the principal nations on patent matters, among other things provides that where any national of the Convention countries files an application in one of the Convention countries, he may file applications in the remaining Convention countries as of the

date of his first filing, providing that he files all of his applications for patents within one year from the date when the first was filed. This provision of the law and the requirement of the preliminary statement rarely affects a citizen of the United States because in nearly all cases, the citizen of the United States chooses first to file in the United States. It is of great importance, however, where the applicant happens to be a foreigner such as, for example, an Englishman, a Frenchman, or a German, who has filed first in his own country, and then within one year files in the United States. If his United States application should get into interference, he is entitled to a constructive reduction to practice as to everything shown in his foreign case which was filed within the year before he filed his United States application.

Where the invention has been made abroad and has been reduced to practice abroad, then the applicant in the United States, if he relies upon a foreign application, must swear that he is the inventor of the subject-matter of the counts because in many foreign countries the application may be filed by some one other than the inventor. He must also state whether the invention has been patented abroad. The reason for this is that if he has some patent which was filed earlier than the United States patent, he is entitled to the benefit of the filing date of the earlier application, providing it is within one year from the filing date of the United States application. If, on the other hand, he has filed abroad more than one year before he filed in the United States and the foreign patent has issued on such application before he filed in the United States, the foreign patent will constitute a statutory bar against his obtaining a patent in the United States and the Patent Office wants this information before it proceeds with the interference.

He is required to state whether or not the invention has been described in a printed publication. If it has been described in a printed publication, that publication facilitates fixing the date of inventorship. If the publication has reached the United States before he filed his United States application, it is of substantial value in establishing the case for the foreign inventor.

The next and one of the most important elements required in the preliminary statement for a foreign inventor is that the foreign inventor shall give the date and circumstances as to when the invention was first introduced into the United States. This introduction may be by the way of a publication such as above referred to; it may be by the way of forwarding a copy of his foreign applications to a United States attorney; or it may be by the applicant himself arriving in the United States. Where the applicant arrives in the United States, a question may arise as to whether the invention has been truly and really introduced into the United States prior to his having disclosed the invention to someone who resides in the United States. It is, therefore, advisable that a foreign inventor shall disclose his invention as soon as he arrives in the United States. It is better if he files a complete application for patent in his own country and then, within the one year period, follows that up by filing his application in the United States. In the latter case, his proofs are greatly simplified because as stated he gets the benefit of the record of his foreign application.

The preparation of a preliminary statement should be painstaking and should be based upon a careful investigation of the facts. The Patent Office recognizes this and where difficulty is being encountered in digging up the facts, ordinarily the Patent Office, upon the request of the inventor, will grant an extension of time, usually twenty or thirty days, in which to investigate as to the necessary information. If any further time is required, the Patent Office usually will demand that the inventor bring a motion asking for additional time, based upon affidavits setting forth the reasons for the further delay to file his preliminary statement. Sometimes an opposing attorney is willing to agree that more time may be had. Where this is the case, the attorneys both sign a paper termed a "stipulation" whereby it is agreed that additional time for preparing and filing preliminary statements may be granted. Usually, the Patent Office will extend the time in accordance with the stipulation. Sometimes, if the time has been extended once or twice by the Patent Office, the Patent Office will grow impatient and will require a verified statement as to why additional time is necessary even though the attorneys have stipulated that additional time may be granted.

When the preliminary statements have been prepared, as specified, these statements must be signed under oath by the inventor. They are forwarded to the Patent Office in a sealed envelope which contains only the preliminary statement. The envelope should bear a designation as to the title of the interference and a statement that this is the preliminary statement of a designated person. These envelopes are not opened by the Examiner of Interferences until after the time for filing preliminary statements has expired.

Renovizing Power to be Theme of Chicago Exposition

Engineers attending the 6th Midwest Engineering and Power Exposition at Chicago during the week of June 25th to 30th will find a new word for their vocabularies which comes from Philadelphia. "Renovizing" power will be the theme of the exposition, or in plain English "repair, remodel, and restore" power plants, utilizing today's improved equipment and supplies.

Leaders in the power field will discuss the specific problems of their industry in relation to present-day conditions with the idea of outlining practical plans for rehabilitation or "renovizing" as a good business proposition. The Century of Progress will add mental stimulation because of its presentation of widely diversified modern scientific and industrial achievements.

The Northern Equipment Co., Erie, Pa., announces the appointment of George W. Neale as district representative for Copes Feed Water Regulators, Differential Valves, Pump Governors and allied equipment for the State of Florida, with the exception of Jefferson County and the counties west thereof. His office is located at 504 East Lafayette St., Tampa, Florida.

NEW EQUIPMENT

of interest to steam plant Engineers

New Portable Air Compressor

Ingersoll-Rand Company, 11 Broadway, New York, has developed a new portable air compressor which represents an advance in this class of equipment since it came into use more than twenty years ago. The new machine adapts the advantages of two-stage stationary compressors and makes them usable in portable units for the first time.

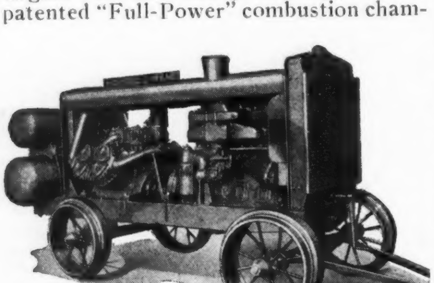
These improvements are claimed to give the new compressor economies and efficiencies never before attained in portable machines. Tests show that, size for size, the new compressor will deliver 23 per cent more compressed air than previous models. Expressed in another way, it will produce an equal volume of air with 25 per cent less fuel.

The compressor in the new machine is a two-stage, air cooled unit. It has two low-pressure cylinders, arranged in a V, and between them, in vertical position, a high-pressure cylinder. The efficiency of two-stage compression is claimed to give the new portable a decided advantage in general service and particularly so at high altitudes and in hot climates. Adoption of air cooling eliminates the danger of freezing and keeps the size and weight of the assembly within reasonable limits.

Partially compressed air from the low pressure cylinders passes through an intercooler. Cooling is effected by air drawn through the intercooler network by a fan. The intercooler efficiency is such that the air is discharged from it into the high-pressure cylinder at a temperature only a few degrees higher than the prevailing atmospheric temperature.

The temperature of the air at the compressor outlet is 200 deg. fahr. cooler than that from the water-cooled, single-stage machines.

A Waukesha four-cylinder gasoline engine of the heavy-duty type with patented "Full-Power" combustion chamber, designed expressly for this service, supplies the power.



Improved regulation for the compressor is provided. Inlet valves play no part in this and are free to perform their primary functions. The speed of the machine is automatically reduced when unloaded.

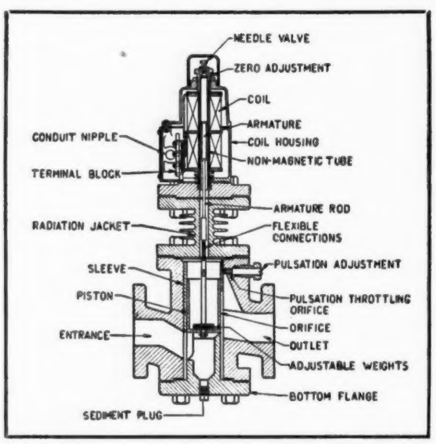
The new two-stage, air-cooled portable is made in four sizes which have piston displacements of 125, 185, 250, and and 370 cubic feet per minute. It is obtainable in a variety of mountings.

Flow Meters

The Brown Instrument Company has developed and is now manufacturing another type of flow meter. This new meter, The Brown Area-Type Flow Meter, has been developed to measure the flow of certain fluids, such as heavy oils, chemicals, food-stuffs, etc.

The Area-Type Flow Meter is a meter of the constant head, variable orifice type. The head, or pressure drop across the orifice is held constant while the size of the orifice opening is varied.

The successful operation of the Area-type meter depends upon the method used to transfer the motion of the piston to the recording or indicating meter. This is accomplished in the Brown Area-Type Meter by using the inductance bridge principle. Transferring the motion of the piston electrically eliminates stuffing boxes, links, levers, etc.



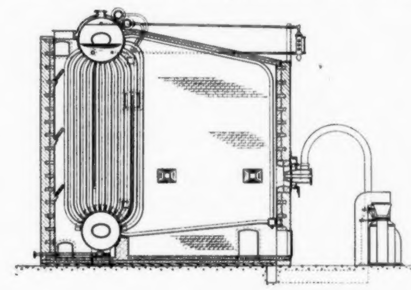
The Brown Area-Type Flow Meter was developed primarily to meet the demand of the Steel Industry for a sensitive, accurate simple and reliable flow meter for the measurement of viscous oil. The desire for extreme economy in operating open hearth furnaces has made it necessary to maintain accurately a fixed rate of firing, and hence to measure accurately the rate of flow of fuel.

From this specialized beginning this new meter has branched out to the extent that many plants upon becoming familiar with this new Brown Flow Meter find that at last it will be possible for them to handle a special flow problem that has bothered them for years. The simplicity of design and construction of the Brown-Area-Type Flow Meter makes it applicable for measuring the flow for many different types of fluids under various operating conditions.

New Steam Generating Unit for Small Plants

Combustion Engineering Corporation announces the C-E Steam Generator Unit, a standard design built in a range of sizes for capacities of 8.000 to 40,000 lb. of steam per hour. The principal features of this unit are its economy of first cost and operation, its compactness, and its suitability for firing by pulverized fuel, oil or gas. It comprises an assembly of standard equipment, and involves no radical departures from established practice. Its low head-room and small floor space requirements make it particularly suitable for the limited space conditions found in many plants. The fact that it may be fired by pulverized fuel, oil or gas provides the advantages of wide choice of fuels, ability to pick up or drop load quickly, high average efficiency and no banking losses.

The general character of the design is shown by the accompanying illustration. The unit comprises a two-drum



vertical boiler and a furnace of solid brick walls, the top and front of which are water-cooled by tubes connecting into the upper boiler drum and terminating in a header in the lower front wall. A water screen across the furnace bottom connects this header with the lower boiler drum. Pulverized fuel is fired horizontally by a natural draft burner to which fuel is supplied by a Raymond Impact Pulverizer Mill, located either in front or to one side of the unit. The boiler can be arranged for either two or three gas passes and may be equipped with a superheater.

C-E Steam Generator Units are installed at a single price, under a single contract, and a single performance guarantee.

New Type of Boiler Tubing

Steel and Tubes, Inc., Cleveland, Ohio, a subsidiary of the Republic Steel Corporation, announces the development of electric resistance weld boiler tubes, to be marketed under the trade name of "Electrunite Boiler Tubes." These new tubes have been recommended by the American Society of Mechanical Engineers for use in pressure boilers. Before publicly announcing this product many installations were made and closely observed for operating characteristics.

The tubing is formed from strip steel continuously, the strip being passed through a series of forming rolls. The round butted tube thus formed then passes under revolving wheel-like copper electrodes where current travels from electrode to electrode through the butted seam of the tube. At the same time, pressure is applied which, together with the heat which is below the fusion temperature and which is confined to an area no larger than a pinhead, completes the weld.

This is the first departure in boiler tube practice for many years, as heretofore only seamless and lapweld tubes have been acceptable for use in boilers.

This new type of boiler tubing is available in all sizes up to 5 in. O. D., in copper bearing, nickel steel and Toncan iron, as well as the usual open hearth steel.

NEW CATALOGS AND BULLETINS

Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Ash Handling Equipment

A new catalog entitled Hydro-Ash describes and illustrates the ash handling equipment manufactured and sold by the Hydro-Ash Corporation, 115 South Dearborn Street, Chicago, Illinois. Basically this system consists of a sealed ash pit hopper from which the ash is sluiced by high velocity water jets into an enclosed trench along which it is sluiced by booster jets if the ash is to go only a short distance. Other conditions are met by special arrangements. This catalog contains sketches and photographic illustrations. 14 pages and cover, 8½ x 11.

Boiler Water Treatment

A new catalog has just been published describing and discussing the Nalco (National Auminate Corporation) system for boiler water treatment. This attractively arranged catalog has the following main headings: How Much Water Treatment is Enough—Combining Scientific Principles with Simplicity —Control—Service—Feeders—and Cost. Diagram and illustrations. 14 pages and cover, 8½ x 11—National Aluminate Corporation, 6216 West 66th Place, Chicago, Illinois.

Boilers

A catalog entitled Union L-Type Boilers has been published recently. This boiler is designed for limited space conditions and is claimed to combine unrestricted circulation, full steam liberation surface in both upper drums, dry steam and high capacity. It is available in sizes ranging from 84 hp. to 513 hp. This catalog is handsomely illustrated and includes tables of horsepower, rating and dimensions and several line drawings. 12 pages, 8½ x 11—Union Iron Works, Erie, Pa.

Compensated Temperature Control Instruments

Bulletin No. 3000-c comprehensively sets forth the design and construction features of Mason-Neilan Compensated Temperature Instruments. This catalog is profusely illustrated with diagrams, layout and photographic reproductions. It also includes charts and tables of list prices and other data. 32 pages, 8½ x 11—Mason Regulator Company, 1190 Adams Street, Dorchester Center, Boston, Mass.

Designed Piping

A folder entitled "Designed Piping" contains a discussion presented at a Joint Meeting of the New York Section, American Welding Society and the Petroleum and Power Division of the A. S. M. E., prepared by F. S. G. Williams. The folder in addition sets forth the essential features of Taylor piping. Several illustrations are included showing contrasting elbow piping designs. Charts and tables, 4 pages, 8½ x 11—Taylor Forge & Pipe Works Chicago, Ill.

Electric Furnaces

"Falcon" Continuous Electric Furnaces for Hardening, Tempering and Annealing Strip Metal and Wire Products are completely illustrated and described in the enclosed Bulletin No. 280 which has just been received from the printer. This bulletin contains many sketches and photographic illustrations. 16 pages, 8½ x 11—H. O. Swoboda Inc., 3530 Forbes Street, Pittsburgh, Pa.

Electric Heating Units and Devices

This small book, entitled as above, contains the answers to many small heating problems that present themselves daily in industrial plants. This catalog sets forth many types of small heating devices and units which find application in industrial plants. Charts, tables, curves and other statistical data on heating are included. 36 pages and cover, 8½ x 11 — General Electric Company, Schenectady, New York.

Electric Steam Generators

Bulletin 1010 describes and illustrates the Kaelin Electric Steam Generator. This generator is of the electrode or water resistance type in which an electrode or electrodes project downward from their insulating supports on the top head into the water, and the heat is generated by the passage of the current through the water itself. Charts and tabes, 8½ x 11, 12 pages—Combustion Engineering Corporation, 200 Madison Avenue, N. Y.—Licensee for U. S. A.

Feedwater Treatment

A "Clean Boiler Story" is the title of a new bulletin, recently published, describing how boilers in many plants are kept in continuous service for long periods by maintaining them free from the troubles of scale, corrosion, wet steam, etc. The installations described are of different types and operate under widely varying conditions throughout the United States and Canada. 24 pages, Hagan Corporation, Pittsburgh, Pa.

Flexible Couplings

Folder 1341 describes and illustrates the new Link-Belt "RC" Flexible Coupling. This coupling is claimed to be easy to handle, durable, reliable and efficient in service, and consists of two cut-tooth sprocket wheels or coupling halves and a piece of roller chain to connect them. A pin-and-cotter link makes it easy to couple or remove the chain when desired. Tables giving dimensions, list price, horsepower and other information, are included. 8 pages, 8 x 9—Link-Belt Company, 519 N. Holmes Avenue, Indianapolis, Indiana.

Flow Meter

A pamphlet entitled Isometer For the Accurate Measurement of all Liquid Flows, describes a new flow meter which is claimed to be small, reliable, trouble-free and moderately priced. The design and operation of the meter and its several parts are set forth. Tables showing pressures and sizes are included. 8 pages, 8½ x 11—Isometer Company, 2357 No. 29th Street, Milwaukee, Wisconsin.

Hand Tachometers

Circular No. 106 describes the new Automatic Fixed Reading Tachometer for speed measurement of revolving equipment as motors, pulley shafts, belt surfaces, etc. 1 page, 7¾ x 10½, Amthor Testing Instrument Company, Inc., 309 Johnson St., Brooklyn, New York.

Refractory

A new pamphlet has been recently issued describing the Steel Mixture Oil Brick and setting forth the qualities and various shapes in which it is available. "Steel Mixture" is a composition of flint clays of the proper balance between silica and alumina, mined in the Clearfield District in Pennsylvania. A table of brick dimensions is included., 16 pages 3¼ x 6¼—McLeod & Henry Company, Troy, New York.

Steam Traps

Bulletin No. 428A, entitled Nicholson Super-Trap, describes the construction and design for Nicholson Super-Traps. These traps are adapted for draining steam purifiers and places where a large capacity trap is required. For pressures ranging from 2 to 600 lb. per sq. in. 4 pages, 8½ x 11—W. H. Nicholson and Company, 12 Oregon Street, Wilkes-Barre, Pa.

NOTICE

Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature
COMBUSTION
to
200 Madison Ave., New York

BOOKS

1—Fan Engineering (Third Edition)

622 Pages 4⅜ x 7 Price $3.00

The Buffalo Forge Company, Buffalo, N. Y., has just issued the third edition of its book, *Fan Engineering*, which is a complete, up-to-date and reliable treatise on the theory and practice of fan applications for all purposes. As with the previous editions, most of the material contained is original, and many of the tables and charts are based on research done expressly for this publication.

The subject matter of the book has been divided into three parts, as follows:

Part I deals with the physical properties of air, heat and humidity, as well as the flow of air in general and as regards the fan in particular.

Part II relates to the application of air and air movements to the various classes of work for which fans may be adapted, such as heating, ventilation, humidifying and dehumidifying, cooling and refrigeration, drying, combustion and mechanical draft, dust elimination, etc.

Part III contains performance tables and general information concerning standard apparatus used in fan work.

Bibliographies at the end of each section furnish suggestions for collateral reading. The appendix contains, in addition to the standard test code, 19 pages of miscellaneous and useful engineering data. A very comprehensive index, thoroughly cross-indexed, facilitates reference work.

2—Bailey's Handbook of Universal Questions and Answers (Sixth Edition)

264 Pages 4¾ x 6½ Price $2.00

The questions and answers contained in this Handbook are those that have been universally asked by examining boards and were compiled from over four hundred examination papers, including tests for firemen, engineers and boiler inspectors. It gives information on the subjects of boilers, pumps, fuel consumption, valves, heating systems, engines, etc., and will be of assistance not only to those studying for any grade of license in this country or in Canada but also to the practical engineer and fireman.

The author, A. R. Bailey, is intimately acquainted with the needs of practical engineers and firemen and of candidates for licenses, having served as engineer and boiler inspector in the states of Massachusetts, Ohio, Pennsylvania and Michigan, and as safety engineer for the Lincoln Motor Company, Detroit. The sixth edition of this book, recently published, has been brought thoroughly up to date.

3—General Engineering Handbook (First Edition)

Editor-in-Chief
Charles Edward O'Rourke

922 Pages Price $4.00

The plan for this handbook, according to the editor-in-chief, who is Assistant Professor of Structural Engineering at Cornell University, was conceived in the belief that a great amount of fundamental engineering data could be assembled in a compact pocketbook of not over 900 pages, which would be valuable as a ready reference and hand companion for practicing engineers and for students. The purpose is to supply a compact reference work of important fundamentals for all engineers.

The author seems to have accomplished this in a most satisfactory manner. There are 31 sections, each section dealing with one general subject. Six of these sections contain material which is of importance to all engineers; others belong in the fields of civil, mechanical, electrical engineering, etc. Also engineering mathematics.

The book contains tables and charts useful in the various branches of engineering. An important factor is a bibliography of the important works dealing with the subject, at the end of each chapter. There is also a comprehensive index.

4—Steam Power Plant Engineering

By Louis Allen Harding

777 Pages 6 x 9 Price $10.00

This book, a complete revision of Vol. II of "Mechanical Equipment of Buildings," the publication of which has now been discontinued, comprehensively covers the major problems involved in the design of power plant apparatus, the rating of the apparatus, their corelation in the scheme of power plant engineering, and the economic factors involved in their selection.

Beginning logically with a discussion of fuels and combustion, the author proceeds with the treatment of boilers, furnaces, stokers, pulverizers, oil burners, superheaters, desuperheaters, resuperheaters, economizers, air preheaters, feed-water heaters, deaerating heaters, evaporators, water purifiers, pumps, steam engines, turbines, regenerators, reheaters, condensers, cooling towers, pipes, fittings, valves, heat coverings, accessories, etc.

The information contained in this book is thoroughly up-to-date and in accord with modern practices. It is written by an engineer of wide experience and should prove of value to any engineer whose work and interests lie in the steam power plant field.

Postage prepaid in the United States on all orders accompanied by remittance or amounting to five dollars or over.

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Books Nos. ....

5—Handbook of Chemistry and Physics (17th Edition)

1722 Pages 4¼ x 6¾ Price $6.00

The 17th edition of this well-known and valuable handbook has been subjected to an unusually extensive revision. Material covering more than three hundred pages in the 16th edition has been substantially changed. In nearly all cases completely new and larger tables are presented, involving an increase of over one hundred pages. Wholly new material, to the extent of fifty pages, has been added.

The most important revision has been that of the table "Physical Constants of Organic Compounds," which has been completely recompiled through the co-operation of 125 professors of organic chemistry representing the largest educational institutions in the country, and a number of directors of research of manufacturers of organic compounds.

Other important tables which have been completely revised are: Flame and Bead Tests; Standard Oxidation—Reduction Potentials; Cubical Expansion of Solids; Specific Heat of Gases; Specific Rotation; Wire Tables. A considerable addition has been made to the mathematical section of the book, including a very complete collection of "Integrals" and extensive "Interest Tables."

6—World Economic Survey 1931-32

327 Pages Price $2.50

The first World Economic Survey, issued by the League of Nations, gives a comprehensive review of the development of the world depression up to the middle of January, 1932.

The first chapters set forth the elements of instability in the post-war economic situation, movements of population and of industrial production, the increased rigidity of economic organization, the shifts in international indebtedness and trading relationships resulting from the war. Special stress is laid upon the importance of movements of capital from one country to another and upon the relation of the credit expansion of 1925-29 to such capital movements.

The main body of the Survey consists of an analysis of the developments of the depression in its various aspects:—the disorganization of production, prices and trade; the difficulties that have arisen in the balancing of international accounts; the growth of unemployment; the strain on the public finances of most countries; and the drift of commercial policy towards increasing measures of trade restriction. A final chapter surveys the position that existed in July, 1932, and the various international measures under consideration as a means of escape from the crisis.

7—American Machinists' Handbook (Fifth Edition)

By Fred H. Colvin
and Frank A. Stanley

1140 Pages 4 x 7 Price $4.00

Every section of the Fifth Edition of this well-known manual has been thoroughly revised—some of them have been practically entirely re-written. A great deal of the new material is in the shape of data and methods which have been developed and are now being used in some of the world's leading manufacturing concerns. Another feature is in the insertion of special tables and diagrams to help in estimating and selecting proper equipment for various jobs. Obsolete material has been weeded out, making the book 100 per cent usable and up-to-date.

Boiler, Stoker and Pulverized Fuel Equipment Sales

As reported by equipment manufacturers to the Department of Commerce, Bureau of the Census.

Boiler Sales

Orders for 23 water tube and h.r.t. boilers were placed in February.

	Number	Square feet
February, 1933	23	59,767
February, 1932	37	161,808
January to February (inclusive, 1933)	57	196,276
Total, 1932	641	2,124,361

NEW ORDERS, BY KIND, PLACED IN FEBRUARY, 1932-1933

	February, 1932		February, 1933	
Kind	Number	Square feet	Number	Square feet
Stationary:				
Water tube	25	147,416	13	48,816
Horizontal return tubular	12	14,392	10	10,951
	37	161,808	23	59,767

Mechanical Stoker Sales

Orders for 55 stokers, Class 4*, totaling 11,113 hp. were placed in February by 42 manufacturers.

	Installed under			
	Fire-tube boilers		Water-tube boilers	
	No.	Horsepower	No.	Horsepower
February, 1933	33	4,627	22	6,486
February, 1932	63	8,209	26	8,568
January to February (inclusive, 1933)	83	12,095	35	11,266
Total, 1932	920	122,346	367	139,173

* Capacity over 300 lb. of coal per hr.

Pulverized Fuel Equipment Sales

Orders for 6 pulverizers with a total capacity of 67,900 lb. per hr. were placed in February.

	STORAGE SYSTEM						
	Pulverizers				Water-tube Boilers		
	Total Number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb. coal per hour for contract	Number	Total sq. ft. steam generating surface	Total lb. steam per hour equivalent
February, 1933	2	..	2	60,000	2	37,000	325,000
February, 1932	..	..	..	......	..	......	......
January to February (inclusive, 1933)	2	..	2	60,000	2	37,000	325,000
Total, 1932	..	..	..	......	..	......	......
	DIRECT FIRED OR UNIT SYSTEM						
	Pulverizers				Water-tube Boilers		
February, 1933	2	1	1	6,400	2	8,300	42,340
February, 1932	12	10	2	74,188	10	75,911	742,200
January to February (inclusive, 1933)	12	11	1	79,000	7	72,734	697,340
Total, 1932	73	48	25	392,388	64	463,194	3,536,260
					Fire-tube Boilers		
February, 1933	2	2	..	1,500	2	2,500	8,000
February, 1932	..	..	..	......	..	......	......
January to February (inclusive, 1933)	3	2	1	2,750	3	4,000	18,300
Total, 1932	13	2	11	13,300	13	20,310	114,650

ADVERTISERS

in this issue

Sectional Committee on Coal Classification Has Annual Meeting

The annual meeting of the Sectional Committee on Classification of Coal, functioning under A.S.A. procedure and sponsored by the American Society for Testing Materials, was recently held in New York City.

A report on the properties of lignite suitable for combustion in pulverized form was submitted to the Technical Committee on Use Classification by Dr. A. W. Gauger of Pennsylvania State College. T. W. Harris, of the duPont Co. reported that his subcommittee had presented their report for publication by the A.I.M.E. on "The Use Classification of Coal for Stationary Steam Generation." Dr. H. J. Rose, of the Mellon Institute, suggested a key symbol that is being developed by the Technical Committee on Scientific Classification, which will place a coal in its proper position both as to scientific classification and as to its most practical factor in use, namely, its B.t.u. as purchased.

At the meeting of the Technical Committee on the Scientific Classification of Coal, considerable progress was made in bringing to a focus the various facts and data on coals that have been collected during the past five years.

The committee gave detailed consideration to Report No. 1 of Subcommittee IV on the Tentative Classification of Coal. After an extended discussion of factors affecting the boundary lines of the different classes of coal, it became evident that no further progress could be made unless governmental agencies, state and national, could be induced to assign a part of their staff to the actual work of making the necessary studies whereby exact boundary lines for classification of coals could be set up. Accordingly, a new subcommittee, known as Subcommittee V on Coal Classification Boundary Lines, was appointed, with W. A. Selvig, of the Pittsburgh Experiment Station of the Bureau of Mines, as chairman. It is hoped to formulate tentative classifications by type and rank within the next six months and present them at the fall meeting of the committee.

Joint Meeting of Subcommittees on Determination of Grindability and Friability of Coal

A joint meeting of Subcommittees on the Determination of Grindability and Friability of Coal, of A.S.T.M. Committee D-5 on Coal and Coke, was held prior to the meeting of the A.S.A. Sectional Committee.

Mr. Van Brunt, chairman of the Subcommittee on Grindability, presented a report by R. A. Sherman, of the Battelle Memorial Institute, which gave the final results of the investigation on the use of absorption of dyes for determining increased surface produced by grinding coal.

Mr. Gilmore presented a report of the work done during the past year in the Fuel Research Laboratories of the Mines Department of Canada at Ottawa.

On behalf of the Subcommittee on Friability of Coal, Mr. Gilmore, the chairman, presented an interesting account of the work that had been done during the past year by various laboratories on methods for determining the resistance of coal to handling.